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MONOFRAX REFRACTORIES

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The term "Monofrax" has been chosen to designate a series of new super refractory materials developed at Mellon Institute in cooperation with the research laboratories of The Carborundum Company. These new refractories are the outcome of about six years of intensive development work although Dr. Frank J. Tone, President of The Carborundum Company, had long previously done considerable pioneer work in this field and had envisioned the utility of this type of product.

A number of large scale installations of "Monofrax" have already been made in the construction of glass melting furnaces and of furnaces for the handling of molten slag. Because of the highly satisfactory performance of these refractories in such applications, numerous additional installations have been arranged for the immediate future. Several installations of various sorts have been made in other industries as well, and it is expected to expand them as time and facilities permit. This paper will deal chiefly with the efforts to develop a series of cast fused refractories suitable for use in glass tanks.

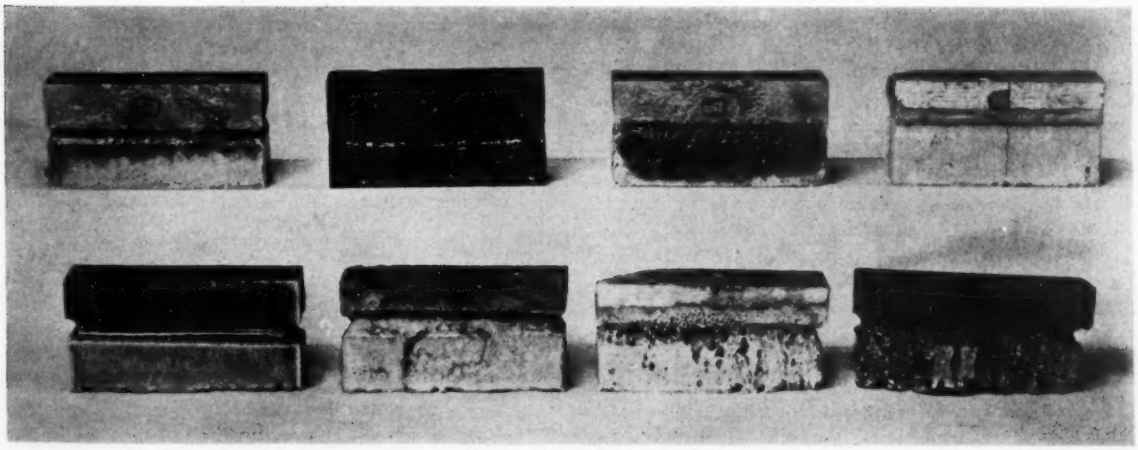
Historical Aspects

The electric furnace was the fore-runner of the super refractory industry. The high temperatures which it made available rendered it possible to produce materials of greater refractoriness than any previously obtainable. The first super refractory material was silicon carbide[1], discovered in the early nineties by Edward Goodrich Acheson, founder of The Carborundum Company. The success of Acheson's experiments with the electric furnace pointed the way to others and in 1900 Chas F. Jacobs was granted[2] a patent for the manufacture in an electric furnace of fused alumina from hydrated aluminum oxide. Later, this material, crushed and bonded, became the second super refractory.

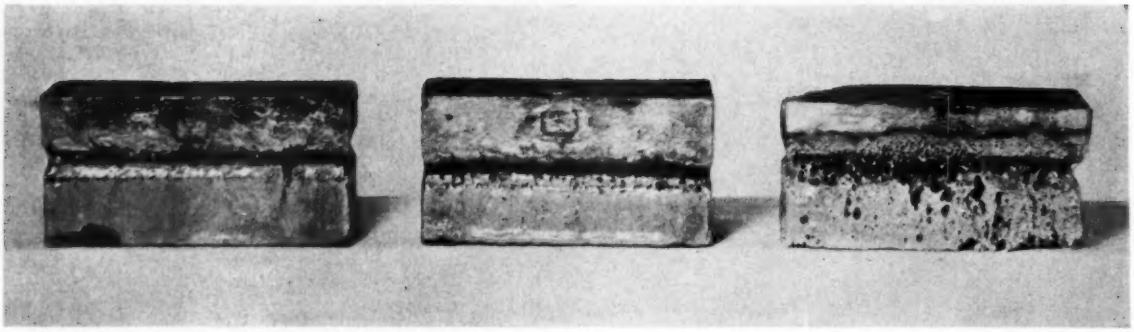
In its work on the production of silicon carbide and fused alumina, The Carborundum Company acquired a wide knowledge of the peculiarities and eccentricities of the electric furnace which was utilized in melting many materials and studying them. In consequence of these investigations, patents on such materials as fused mullite[3], fused magnesia spinel[4] and fused chromite[5] were granted to The Carborundum Company. It is interesting to note that the discovery of the remarkable refractoriness of the first of these, namely, mullite, antedated Bowen & Greig's historic paper[6] identifying and naming the mineral by nearly fifteen years.

The possibilities inherent in the electric furnace as a tool in the manufacture of super refractories stimulated others and in 1927 the first[7] of several patents to Gordon S. Fulcher and associates on cast fused refractories and methods of manufacture, was issued. These were assigned to the Corning Glass Works. Later the Corhart Refractories Company was organized with rights to manufacture under these and other patents.

Dr. Tone's interest in the electric furnace as a means of producing super refractories continued uninterruptedly from his first association with The Carborundum Company. Referring to his pioneering work on cast fused mullite and other materials he stated in his Acheson



● *Illustrating the difference in attack by a soda-lime glass on a number of cast fused mixes. In some, appreciable corrosion occurs only at the metal line. In others attack occurs over a good portion of the surface.*



● *This photograph of three experimental cast fused mixes illustrates the frequently encountered fact that there is an optimum amount of the addition agent while the one at the right contains several per cent. The one in the center contains an intermediate amount, and, while the photograph does not show it completely, is considerably superior to the one at the left.*

Medal address[8]: "Directly or indirectly through the use of the electric furnace there had been developed a new art in the refractory field, consisting in selecting natural ores to give specified compositions and fusing them in the electric furnace, and the ability to cast these in molds opened up a field of products sharply distinguished from bonded refractories made after the old technique." Accordingly the problem was suggested to Mellon Institute in 1932 and has been under continuous investigation there since then with satisfactory results.

Approach to the Problem

At this time it would be well to digress for a moment in order to emphasize that, in the usual refractory, the bond is the point of weakness. Corrosion and erosion take place not only on the surface but attack occurs also in the pores, dissolving or destroying the bond and thus dislodging refractory material even before it is dissolved.

The obvious solution of the problem is to use a homogeneous casting of the more resistant material. With a cast fused refractory it is possible to secure a dense impermeable, impenetrable structure in which attack is limited almost entirely to the face.

Early in this development work it was recognized that there was no universal cast fused refractory; i.e., that a material which might show excellent service under one set of conditions might be inferior when tried out for another purpose. Thus the best refractory for a soda-lime glass may not be the most desirable for a boro-silicate glass, and the one best suited for an opal glass may not be the most satisfactory for a plate glass. As pointed out earlier, practically any refractory oxide or mixture of oxides can be fused in an electric furnace and many of them can be cast; consequently, the resultant possibilities are manifold. Further, the investigations have shown that even slight changes in composition frequently cause marked differences in the properties and behavior of the finished refractory.

Early in the development work the petrographic studies confirmed the same fact that a number of investigators had already recorded; namely, that the most stable phase occurring at the interface of glass and refractory after a flux block of clay or other type had been in use for a long period of time was alpha alumina. In some cases these crystals were originally present in the block, the removal of the other material leaving them as the residual mass; in other cases, the silica seemed to have been removed from the mullite crystals, accompanied by conversion of the residual alumina to alpha-corundum crystals.

In view of this stability of alpha-alumina towards the raw glass batch and molten glass, a great deal of study was devoted to the problem of getting this material into a form most suitable for glass tank use. It was found that for a number of reasons it is frequently desirable to modify the composition, and in this manner, the properties and structure of the material to be used for tank blocks. In addition, a number of rather complex mixes of very moderate or practically no alpha-alumina content were discovered which have given remarkably satisfactory results when installed in glass tanks.

It would be well to emphasize here that, in studying the tank block problem encountered in the glass industry, there are two complementary viewpoints from which it must be considered, viz:

(a) The attack on the refractories by the raw batch constituents of the glass and by the molten glass, and

(b) The contamination of the glass by the attack on the refractories with the possible formation of seeds, stones and striae.

In several cases it has been thought that carbides or carbon in the refractories used in contact with the molten glass may have been responsible for seeds in the glass. But, so far, this is mere conjecture; at least research has supplied as yet no data that are at all conclusive. But with this in mind several "Monofrax" mixes have been developed with the express purpose of completely eliminating any such possibilities.

Testing Procedure

Considerable study was given to the matter of devising a satisfactory preliminary test. Purely laboratory tests were deemed inadequate and a small gas-fired day tank was therefore set up in a glass plant under conditions which approximated those of commercial work. Test pieces of hundreds of different compositions were cast into 2 x 2 x 4" pieces or broken to approximately this size from larger pieces in order that the interior structure could be tested as well as the surface.

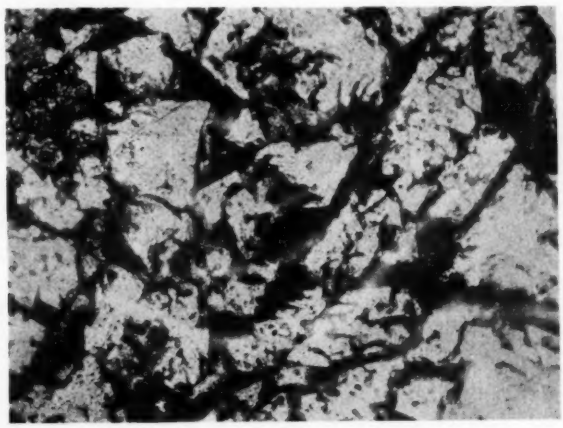
After the blocks were placed in an empty tank, raw batch was shoveled in through the doors and over the test specimens so that when melted down it would cover the pieces to a depth of about two inches, thus giving a metal line about half-way up the test pieces. In these "half-immersion" tests three general types of glasses were used: (a) a high soda-lime glass containing some-

what more alkali than usual; (b) a boro-silicate glass; and (c) an opal or fluoride glass. After the blocks had been exposed to the action of the glass at commercial temperatures for 100 hours, the blocks were removed from the tank and cooled, and then examined by various means and evaluated in comparison with standard mixes included in this same test. Since the entire blocks were subjected to furnace temperatures the test was accelerated as compared with normal operating conditions. On the basis of these preliminary tests many of the mixes were eliminated from further consideration and the best mixes were further tested by a variety of methods.

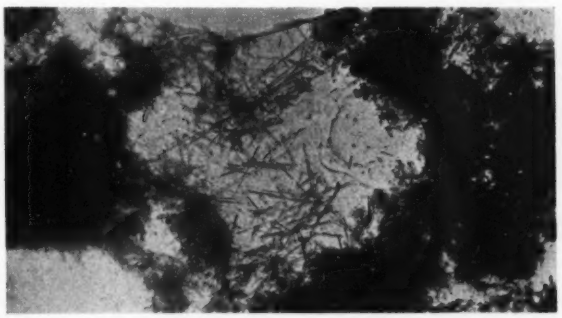
One of the most satisfactory schemes was what is termed an "accelerated bridge-wall test," in which standard 9" straights were placed on their 2½" by 9" face in the bridge-wall of a small continuous tank and supported on either end of this face. Molten glass extended about two-thirds of the way up the 4½" dimension. The entire brick was at furnace temperature and all surfaces except the top were subjected to the action of the molten glass. The specimens were then compared with the different standard flux blocks subjected simultaneously to the same tests.

There is another type of test which, while not ranking in importance with the others, nevertheless has given us some interesting data. Orifice rings of a commercial glass feeding device were made from a number of different "Monofrax" mixes. In many instances, operating necessities forced the removal of the "Monofrax" rings before their period of usefulness had terminated, but many rings of the best mixes gave service against a variety of glasses of from 40 to 50 days, and in some cases as high as 100 days. It is of interest to note that one of the mixes referred to later as "Monofrax" 'K' showed some remarkable properties in these tests. Apparently at the temperatures involved this particular mix is not even wetted by the glass with a consequent minimum of corrosion.

In all this extensive exploratory work, constant use was made of the scientific tools which have done so much to illuminate the path of the trained research worker. Hundreds of thin sections were made of the refractories both before and after tests, and studied carefully under the petrographic microscope. The analytical chemist also contributed his efforts. Frequent photographs were made for later reference and in order to provide a permanent record of the work. Even the X-ray was pressed into service in order to increase the knowledge of the constituents, and to ascertain the crystal structure. A high temperature microscope through

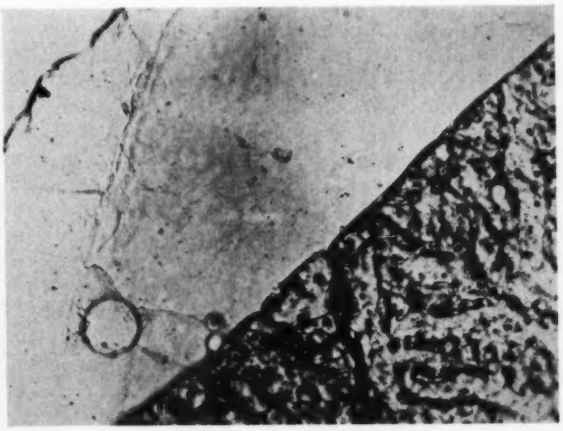


The microstructure of a Monofrax L showing the dense crystalline structure. Ordinary transmitted light. x 80.

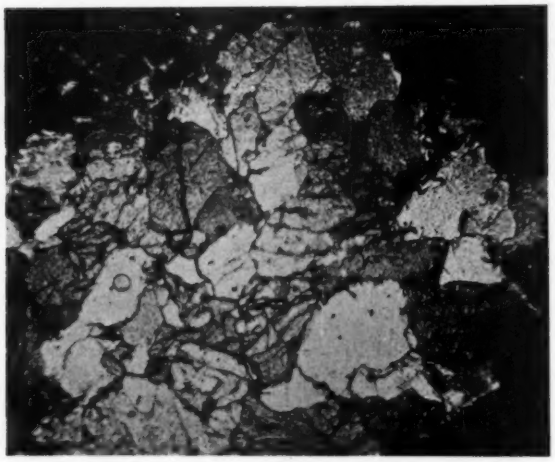


The glass refractory interface of a clay flux block showing the penetration of the refractory by the glass. The light colored areas are glass. The needle-like crystals are mullite and result from devitrification. Note the complete lack of a sharp boundary line between glass and refractory at their interface. Ordinary transmitted light. x 150.

The microstructure of a Monofrax K block showing the dense interlocking structure consisting of two crystalline phases. Ordinary transmitted light. x 100.



The glass refractory of a Monofrax H block. Note the absolute impenetrability of the refractory by the glass. The lack of any sign of devitrification is one indication of the very negligible chemical attack. Ordinary transmitted light. x 200.



The microstructure of a typical Monofrax L refractory which is shown to consist chiefly of closely packed crystals of alpha ammonia. Crossed Nichols. x 30.

which motion pictures could be taken was developed. By means of this thermal microscope it was possible to observe, and with the "movie" attachment to record the mechanism of the attack by molten glass and slags on various "Monofrax" refractories and other refractories as well. It has proved an extremely useful tool. Incidentally, the films which have been taken have been very much in demand for technical gatherings, and have induced considerable technical interest.

Large Scale Tests

Coincidentally with this study of compositions and structure as briefly outlined above, and utilizing the information thus obtained, many large scale tests of various mixes have been made. The walls of a day tank, except for a few comparison blocks of standard refractories, were completely constructed of "Monofrax," using five different mixes. This tank was in operation for a little over thirteen months. Eventually it was dismantled, not because of any failure on the part of the "Monofrax" blocks, but because it was desired to rebuild it of other "Monofrax" blocks.

This time the entire bottom and the walls up to slightly above the metal line were made of "Monofrax," except for a number of comparison blocks. One of the purposes of this run was to test the influence of size of the castings upon the results. Hitherto in glass-tank construction it has been the practice to make the blocks as large as possible, chiefly in order to eliminate the joints, which are the focus of attack. However, many of the "Monofrax" mixes have shown such extraordinary resistance to corrosion at the joints, as compared with other materials previously available, that it was thought that the greater ease and convenience in handling smaller shapes would make their use preferable notwithstanding the increase in the number of joints. This tank has been in service over two years now, with very pleasing results. The edges and corners of all shapes, including the smallest ones, are sharp and distinct, thus holding out the hope that it may be permissible and even desirable to use smaller blocks in tank construction with all the attendant advantages.

Then, too, in order to subject "Monofrax" to the most severe service conditions possible, blocks of a number of the preferred mixes have been placed at the metal line in the neighborhood of the first two or three ports in a good many commercial tanks. Tests of this type have been under way for some time and have served to demonstrate the very satisfactory behavior of the "Monofrax" mixes selected for trial.

Also, panels of a number of mixes several feet in width and extending to the bottom of some of the largest commercial tanks have been installed. None of these tests has yet been run to completion, but in those cases where examination of the blocks has been possible the "Monofrax" mixes have shown up splendidly.

An entire continuous tank has been constructed of one of the preferred mixes and has been in active service now since April 1 on a specialty glass where the requirements are very severe both with respect to quality and temperature. Other than the usual adjustments encountered in putting a new material into service, results have been quite satisfactory. After several months of service this tank was drained to change over to another glass, thus affording an excellent opportunity to examine the tank interior. The remarkable fact apparent from this examination was the quite negligible amount of corrosion even at the metal line after a period of time during which the standard refractories may undergo corrosion at this point equal to half the thickness of the material. Further, it is interesting to note that operations had been conducted a good portion of this period with about 2½" of panel insulation on the tank, thus denying the "Monofrax" the usual temperature gradient through the block and the consequent cooler temperature at the glass interface that usually exists. Ordinarily, tank operation is carried on with positive air cooling particularly at the metal line from the moment the furnace is filled. Accordingly the use of insulation is a substantial departure from past procedure and, in view of the negligible corrosion that has been observed, would indicate the likelihood of a very substantial fuel saving over the life of the tank. It would also indicate the possibility of higher tank operating temperatures with all that entails such as a greater through-put of glass for the tank or a glass superior in quality to that formerly produced.

At the present time, in view of the satisfactory results already achieved, a number of additional installations are being made in tanks of some of the large glass companies in all types of glass—window, plate, wireglass, bottle and specialty glasses.

The Characteristics of Preferred Mixes: Physical Properties

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"Monofrax" L is the term used to refer to a group of mixes which contain 90 per cent or more of alumina and for the most part have a very high alpha-alumina content. The addition agents may be one or more of a number of elemental oxides. Obviously, these addition agents modify the chemical composition and as a consequence the casting characteristics, the physical structure and other properties. As a result of these various facts,

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SYMPOSIUM ON OPTICAL GLASSES

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A feature of this year's meeting was a symposium on optical materials. Four of the five invited papers dealt with optical glasses. Although the titles assigned were of such a nature that some overlapping was inevitable, the approach to the subject in each case was quite different.

The following are summaries of the papers read at the symposium. They will be published in full at a later date in the Journal of the Society. The final paper given here, on Thermometer Glasses, did not form part of the symposium, but was read at the opening session as a contributed paper.

Optical Glass Requirements of the Optical Industry, by W. B. Rayton, Director of Scientific Bureau, Bausch & Lomb Optical Co.

A discussion of the needs of the optical industry with respect to glass should proceed from a definition of the material. What is optical glass? A committee of the Optical Society of America has striven to formulate a definition, but without conspicuous success. A definition presumably should enable one to determine by inspection whether a sample were optical glass or not; but in that sense, a definition is impossible. For the present discussion optical glass will be regarded as a material made to conform to specified optical properties and of a degree of physical excellence as high as can be reached in the kind of glass in question.

The requirements of the optical industry can be discussed from the standpoint of quantity, quality and variety.

Quantity—The optical glass requirements of this country are estimated today at not far from 100,000 pounds. Of Ophthalmic glass, a grade between ordinary glass and the highest grade optical glass, the demand is approximately 2,500,000 pounds.

Quality—The manufacturer of fine lenses demands four things in the way of quality, first and foremost being:

1. An homogeneous glass; i. e., one that is free from variations in refractive index, either abrupt or gradual. It is difficult to determine by inspection just how serious in its effect on image quality will be a single heavy stria or a group of fine striae. In general, the single heavy one is the less dangerous. It would be comforting if we could summarily reject all glass in which any striae could be detected, but this is impractical; one does not want to reject glass that costs five to six dollars a pound if it will make good lenses. And the more rigid the inspection, the higher will be the cost of the glass. Nor, on the other hand, does the lens maker wish to pay skilled artisans to work on glass which, in spite of their best efforts, will have to be thrown out eventually.

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3. A glass that is absolutely transparent over the whole visible spectrum. In this respect, the glass maker has attained near perfection. Twenty-five years ago, an absorption of light of one per cent per centimeter was regarded as excellent; today, the best glass absorbs not more than four to six-tenths of a per cent per centimeter, except in the dense barium crowns and the densest flint glasses.

4. A glass that in spite of the optical properties demanded, is resistant to the acids, alkalis, and water vapor encountered in both the usual out-doors and laboratory atmospheres.

The durability of a polished surface of glass depends solely upon its chemical composition. So, also, the optical properties of the glass. In general, then, the durability of polished surfaces must be related to optical properties. Fortunately, this is not strictly true, for glasses can be produced to meet given specifications for optical properties that vary considerably as to their surface durability.

Two kinds of surface deterioration are encountered: 1. Metallic lustre, or tarnish. This is of importance only because of a consumer resistance. Actually, tarnished surfaces have a greater light transmission and a lower Fresnel reflection. 2. Effects due to the sensitiveness of glass to water. Some glasses are hygroscopic. Such glasses collect a film of small liquid droplets by condensation of the water vapor in the atmosphere and eventually this film may lead to the corrosion of the glass and the destruction of the polish of the surfaces.

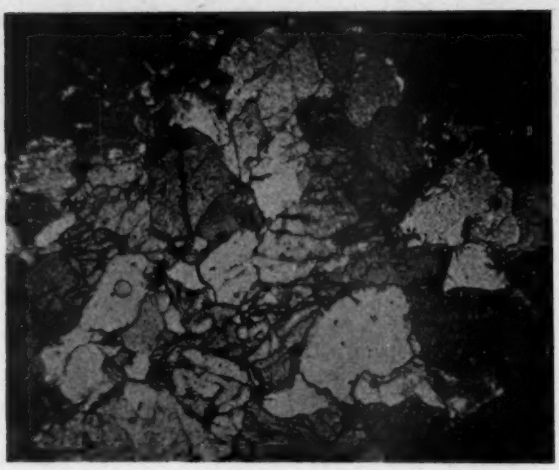
The reagents responsible for these effects are for the most part air-born acids and water. Many efforts have been made to express by some numerical coefficient the surface resistance of glasses to such attack, without much success.

Variety—The number and variety of glasses available are very large, larger than necessary. The combined catalags of the one American and the three principal European optical glass manufacturers contain hundreds of listed varieties of which many, even in the same catalog, are so close to each other that the differences are not greater than the variations in refractive properties that seem to be inevitable in manufacture. The optical instrument manufacturer would welcome glasses whose optical constants lie outside the range of those now available, but within that range it is quite probable that something like 35 types of glass would meet all legitimate demands of the lens designer.

The Availability of Optical Glasses, by G. W. Morey, Geophysical Laboratory.

Optical glass is characterized by the perfection of certain physical properties, obtained by extreme care in manufacture; and by a wide range of optical properties, obtained by changes in the composition. Throughout the manufacture of optical glass, the greatest care is necessary in all details; it is a laboratory process carried out on a commercial scale.

One of the most important physical properties of optical glass is homogeneity. Lack of homogeneity may be



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Two kinds of surface deterioration are encountered: 1. Metallic lustre, or tarnish. This is of importance only because of a consumer resistance. Actually, tarnished surfaces have a greater light transmission and a lower Fresnel reflection. 2. Effects due to the sensitiveness of glass to water. Some glasses are hygroscopic. Such glasses collect a film of small liquid droplets by condensation of the water vapor in the atmosphere and eventually this film may lead to the corrosion of the glass and the destruction of the polish of the surfaces.

The reagents responsible for these effects are for the most part air-born acids and water. Many efforts have been made to express by some numerical coefficient the surface resistance of glasses to such attack, without much success.

Variety—The number and variety of glasses available are very large, larger than necessary. The combined catalags of the one American and the three principal European optical glass manufacturers contain hundreds of listed varieties of which many, even in the same catalog, are so close to each other that the differences are not greater than the variations in refractive properties that seem to be inevitable in manufacture. The optical instrument manufacturer would welcome glasses whose optical constants lie outside the range of those now available, but within that range it is quite probable that something like 35 types of glass would meet all legitimate demands of the lens designer.

The Availability of Optical Glasses, by G. W. Morey, Geophysical Laboratory.

Optical glass is characterized by the perfection of certain physical properties, obtained by extreme care in manufacture; and by a wide range of optical properties, obtained by changes in the composition. Throughout the manufacture of optical glass, the greatest care is necessary in all details; it is a laboratory process carried out on a commercial scale.

One of the most important physical properties of optical glass is homogeneity. Lack of homogeneity may be

due to (a) streaks or regions of different chemical composition, which result in seams, cords or striae. The technique of obtaining a stria-free glass is extremely difficult to master and under the best of manufacturing conditions the yield of stria-free glass is only 25 to 30 per cent of the melt. (b) Lack of homogeneity may be caused also by differences in the thermal history of regions in the glass, resulting in a gradual change in the refractive index between one point and another. This trouble is almost a second-order effect. It is never met with in the glass as it comes from the pot. Caused by improper heat treatment, it can be remedied by proper re-annealing.

Optical glass is available in a wide range of refractive indices and dispersions, and to a limited extent these two properties are independently variable. This is not true of what are called the "older" types, and is chiefly the result of introducing barium oxide.

The older crown-flint series had almost a linear relation between the refractive index and the dispersion, and hence the possible reduction of chromatic aberration was limited. At the bottom of the series was "ordinary" crown, a soda-lime-silica glass essentially the same as window glass in composition.

The introduction of the borosilicate crowns extended the range to lower indices, and the effect of boric oxide in lengthening the red end of the spectrum is especially useful in reducing the secondary spectrum when used in connection with the flint glasses, whose content of lead oxide lengthens the blue. Later came the fluor crowns, still further extending the series to lower indices. Some of the fluor crowns produce significant changes in the index-dispersion ratios.

The optical glasses called flints all contain lead oxide. The soft crowns are transition members of the series, between crowns and flints, and tend to be somewhat inferior to them in durability. The telescope crown is a special glass in this general region, characterized by the presence of a quantity in antimony oxide.

The flints proper range through the light and medium flints, with refractive indices from about 1.55 to 1.65, to the dense and extra-dense flints, with indices up to 1.8 or higher. Higher members of the series contain potash, lead oxide, and silica, with a little arsenic.

The crown-flint series of glasses offer limited opportunities for correcting the secondary spectrum; but the introduction of barium oxide gives glasses differing from the crown-flint series in a notably decreased dispersion. They are grouped into the light barium crowns, dense barium crowns and barium flints.

A greater independence between refractive index and dispersion in optical glass is greatly to be desired, but the possibilities are sharply limited by chemical relationships. All glasses, on cooling from the melting temperature, pass through a temperature range in which the liquid becomes unstable with respect to one or more crystilline compounds. It is at or below this temperature that the glass can be devitrified by appropriate heat treatment. If during the working or annealing process the glass is held too long in the temperature range in which crystallization takes place most readily, it will devitrify and be ruined. This tendency toward crystallization is the chief factor which limits the composition range and imposes limitations which are impassible.

The requirements of physical perfection are less stringent for ophthalmic glass than for optical glass. Striae that are visible when viewed through the surface are not admissable, but fine striae running parallel to the surface do no harm.

The types of glass used in ophthalmic work are small in number compared with optical glass. The most common spectacle glass is similar in composition and properties to an ordinary crown; in fact, it is an ordinary crown. Flint glasses are used for bifocals; usually one with an index of about 1.616 and more rarely 1.65 or higher. Other ophthalmic glasses include numerous tints, ranging from a light smoky glass to the almost opaque welder's glass.

(Dr. Morey then discussed further the availability of various types of optical glass.)

Optical Glass at the National Bureau of Standards, by A. N. Finn, Chief, Glass Division, National Bureau of Standards.

Preliminary work on the making of optical glass for precision instruments was started at the Bureau of Standards during 1914. At that time, the intention was to make glass both for industry and for the government; but subsequently it was deemed expedient to confine production to certain requirements of the government. It is the Bureau's function to study the problem continually, to be able to definitely describe all the operations necessary, and to keep a small force in training, to the end that should an emergency arise, the government is assured of an adequate supply of optical glass for fire control instruments, and that initial mass production will not be seriously delayed.

The Bureau manufactures its own pots from domestic clays, and for its particular purposes, prefers cast pots to those that are made by hand. Contrary to general practice, it does not age the pots a long time; the majority being six months old and, on occasions, as little as three to four weeks old. In the latter case, the pots are pre-heated at a slower rate than normal. All pots are heated to approximately 1425° C and held at that temperature for several hours before being transferred from the pot arches to the melting furnace. It is felt that this makes the pot more resistant to glass attack than arching to a lower temperature and finishing the heating in a short time in the melting furnace, as is the practice in some plants.

Except for minor changes, optical glass is melted and stirred in about the same way as it was during the Great War. However, a significant change has been made in the time required for making a pot of glass. Now we can successfully make a melt of borosilicate crown in 14 hours and the other glasses in not to exceed 24 hours. Fifteen years ago, 36 or even 48 hours was not regarded as an unreasonable time.

The most troublesome condition with which an optical glass manufacturer must contend is striae, which are the result of pot solution and volatilization. The detection and elimination of those parts of the glass containing striae is a problem causing much concern. Their detection does not involve great difficulty after the surfaces of the glass have been polished; but the polishing operation requires considerable time and delays inspection. At the Bureau of Standards, all glass is tested for striae by an immersion method which permits the irregularly shaped

pieces of glass to be inspected as they come from the pot and without any intermediate operations. Inspection by immersion requires considerable practice, but when performed by trained inspectors gives results that are eminently satisfactory.

Although striae are one of the tribulations of the glass manufacturer, stability of glass and reproducibility of optical properties are matters of prime importance to the optical instrument designer. Stability, or resistance to the action of certain atmospheric constituents, is a function of the composition of the glass—and so also is refractivity. The designer concludes he must have a glass of definite, specified indices, in order to make the light rays follow a predetermined path. Then, in order to protect his glasses, he specifies that they must be stable. As soon as he specifies indices of refraction, he tells the glass manufacturer (probably without knowing it) what the glass shall be made of. To this the glass maker does not object; but it might seem presumptuous to expect the glass maker to so change the nature of glass-forming oxides that they will make stable glasses, when nature expected them to make unstable glasses.

A test was made to see what the effect would be on the melting properties and optical constants of a flint (lead) glass if soda were substituted for potash. Such a glass was made in which all the alkali was soda. No appreciable difference in melting properties was noticed. The difference in refractivity was slight—the change could be overlooked in a great many cases.

The Bureau of Standards is frequently asked how closely its glasses conform to the prescribed index of refraction. The following is a summary of all the glasses made during the last five years:

Index (Md) Required	Number of Melts made	Average Index Found	Maximum Departure from Index Required, $+x(10)^5$ —
1.517	157	1.51677	54 87
1.574	69	1.57393	288 163
1.620	23	1.62067	167 93
1.648	16	1.64869	248 126
1.605	2	1.60385	— 168*

*In this case, both values were less than the required 1.605.

From this table, it is evident that more 1.517 glass (borosilicate crown) is made than all the rest combined, and that departures from the required index are less. Probably this is because a rather definite time-temperature schedule has been adopted for making borosilicate crown. Experiments are being made with the time-temperature schedules of other glasses in the hope of securing greater uniformity.

The indices of refraction given in the preceding table were made on samples taken from the pot after the glass was cold. After molding and annealing, the refractivity of the glass will undergo a change, depending upon the time-temperature effect incident to final annealing. Since the conditions required for annealing glass depend on the dimensions of the piece, two different annealing schedules are used—one for small blanks, the other for large prism blanks. In the first case, the refractivity may be increased only by a few points in the fourth decimal; in the latter, by at least one point in the third decimal. As the foregoing indicates, the optical instrument maker should have no interest at all in the optical constants of the glass as it comes from the pot, but need concern himself with its optical properties after the glass has been finally annealed.

The question frequently is asked whether foreign made optical glass is superior to that made in America. There is no significant difference in the behavior of these glasses from any of the several possible sources, provided the glass is free from striae, is properly annealed, and has the desired indices of refraction. The geographic source of the raw materials has no significance, provided the materials are sufficiently pure.

Twenty years ago there was practically no optical glass made in this country, Americans knew little of the technique involved, and some of the essential raw materials were not domestically available. Today, all necessary raw materials can be produced domestically, a large amount of pertinent technical information is available, and there is a considerable experienced personnel. At least two domestic plants are making good optical glass for the most exacting purposes.

Optics and the Glass Industry, by E. D. Tillyer, American Optical Co.

Glass is the most important raw material used in the study of optics and in the design and manufacture of optical and ophthalmological instruments. However, less than one-tenth of one per cent of the tonnage of the glass industry goes into the production of all kinds of optical instruments, including ophthalmic lenses. Glasses for the optical industry must have very special properties. All things considered, we should be grateful to the glass industry for all it has done for the optical industry.

Let us briefly review some of the types of glasses that are available for optical instruments and for ophthalmological purposes, and some of those which we would like to have. Any catalog of glasses lists a range of refractive indices from approximately 1.47 to 1.93 with reciprocal relative dispersions ranging from 70 to 20. Unfortunately, we haven't the low index glass with the same dispersion as the high index, or vice-versa.

While optical glass is somewhat different from ophthalmological, they are approaching each other rapidly. In bifocals today we use a barium glass corresponding to that used in photographic lenses, but it must have three properties which the old photographic glass did not require: 1. freedom from bubbles, 2. coefficient of expansion matching crown glass's from fusion to room temperatures, and 3. resistance to tarnish. The last is imposed because the public doesn't like the tarnish, although more light gets through the lens when it is tarnished slightly.

In the modern fused bifocal, one piece of crown must fuse into another and disappear. This means that the crown's index of refraction must be held to plus or minus three units in the fourth decimal place. But prolonged heat treatment below the fusion point can change the index of refraction by several times this tolerance.

Another need is for absorption glasses with highly selective color transmissions. For ophthalmological purposes we need glasses which cut off the ultra-violet or infra-red spectra, or both. Melt after melt, these glasses must be duplicated so closely, that no difference in tint can be seen on edge-wise examination.

Great improvements have been made in glasses for pro-

tection from high intensity sources. Twenty years ago there was only one commercial welding glass that transmitted less than 25 per cent of the total energy. Now for the same optical density we would consider 0.01 high.

To dream a little about what an optical designer would like to have in glasses: 1. high index and low dispersion, 2. even higher index and considerable dispersion, 3. neighboring refractions with widely different dispersions, 4. widely different refractions and matching dispersions, 5. entirely different partial dispersion ratios from present-day glasses, still near one of them in refractive index and dispersion.

For optical purposes, we would like a glass which transmits far into the ultra-violet and the infra-red. I have just read in Hovestadt's "Jena Glass": "phosphate glasses are all hygroscopic," and then one of my associates hands me a glass with 75 per cent phosphorous pentoxide in it and tells me it is less soluble in water than a high grade crown or boro-silicate crown. We have obtained *stable* phosphate glasses which transmit to 233 mu, with a refractive index of 1.52 and a reciprocal dispersion of 70. Less stable ones transmit to 215.

Another very interesting group of glasses is the zinc borates. They have a refractive index somewhere around 1.63 to 1.65 with a reciprocal dispersion of 50 to 55. We have studied modifications of these by various additions. One is beryllium oxide which makes a most beautiful high index, low dispersion glass of crystal, gem-like clearness, and very resistant to chemical attack. Other elements produce glasses having different properties. One zinc borate strontium combination has an index of 1.60 with a reciprocal relative dispersion of roughly 64. Cadmium borate has the high index of the extra dense flint group with a reciprocal dispersion like the barium glasses. Titanium in the zinc borate glasses raises the index very rapidly.

Dr. Heyne of Osram, Berlin, has described another remarkable group of glasses, the beryllium fluorides with considerable transmission in the ultra-violet. They soften at very low temperatures, and are not stable, *so far*. This is just another example of obtaining unique properties by leaving silica and oxygen out of a glass.

Stability in all glasses is important. Various additions to atmospheric unstable glass can be made which will greatly increase its stability. Sometimes it seems to me that a regular shot gun preparation gives the best results.

Recently a number of synthetic products have been introduced which have exceedingly high transmissions. One of these, Plexiglas, has a refractive index very near the ordinary crowns, a reciprocal dispersion about the same as the ordinary crown, but a ratio of the partial dispersions like extra dense flnts. If this can be repeated, a new factor has been introduced in making a completely color-corrected lens. Others of these new synthetics have different refractive indices and different dispersions. As to their future, I personally hate to predict. Used as exposed lenses they certainly will scratch.

As to the future of optical glasses, I think we have made a start in increasing our range of refractive indices, dispersions and other optical properties. It would not surprise me greatly to see some of our ideals fulfilled. I do not expect to have the refractive index of the diamond, but I do expect to see indices way beyond our present lead glasses, and to have them with transmissions extending further into the ultra-violet. I expect to have absorption glasses way beyond our present demands. I believe we are just at the beginning of a new era in materials for the design of optical systems, instead of having reached the ultimate.

Effect of Aging on Thermometer Glasses, by Bradford Noyes, Taylor Instrument Companies.

For over 100 years it has been known that the volume of a thermometer bulb was subject to after-working, or a change in the properties of the material of the bulb which might affect the reading of the instrument. Person[1] attempted to anneal the bulbs to overcome this difficulty. Special glasses for thermometric purposes were devised by Schott in Jena from 1880 to 1890, among these being the so-called "normal" glasses and the "borosilicate" glasses in common use at the present time. Dickinson[2] studied the effect of high temperature on thermometers of these glasses for as long as 1900 hours. More recently Holburn and Otto[3] have investigated the physical properties of thermometric glasses between the so-called strain and annealing points.

The present investigation shows that the change in the volume of the bulb may be considerable even after tubes have been artificially aged at high temperatures, the amount of the change depending greatly upon the temperature and time of aging.

Thermometers made of "borosilicate" glass and artificially aged are still showing slight changes in the ice point after more than two years, being held constantly at a temperature of 445° C, 490° C rather than 500 or 5550° C, is probably the upper limit at which thermometers of this material should be used continuously. Other thermometers made of "normal" bulb glass and lead capillaries have also been studied and the change of the volume of the bulb measured.

These changes in volume may be due entirely to release of strain, but if so the strains are minute, as even short artificial aging removes all strains visible in a Polariscope.

[1]Comptes Rendus 19, 1314 (1844).
[2]Bul. of the Bureau of Standards, Vol. 2, No. 2.
[3]Zeits. f. Inst. 46, 415-424.

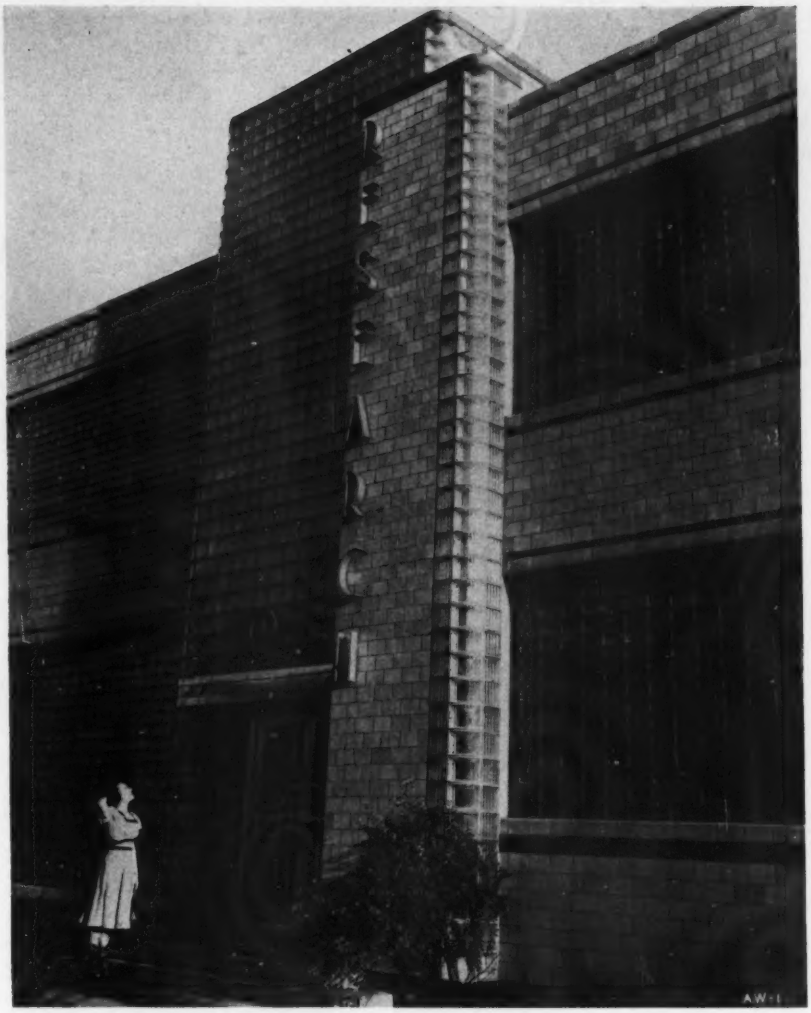
NEW DEVICE FOR STEREOSCOPIC MAPPING

A 25-square mile tract can be "picked up" from an airplane and set down on a table in three dimensions by means of an instrument known as a multiplex projector now being built by Bausch & Lomb Optical Co.

A plane working in conjunction with the aero-projector begins operations over an area containing three points accurately surveyed by traditional methods. As it flies out into unmapped territory, the shutter of an automatic camera looking down clicks at intervals.

The film is then developed and printed on small glass plates which are used as lantern slides in a battery of projectors mounted above a table. The images formed by adjacent projectors on the table overlap just as they do the areas covered in successive photographs. Alternate projectors form their images in red and green light. The user wearing spectacles with one lens red and the other green, sees the overlapped area stereoscopically. He gets the same impression of depth as though he were a giant so huge that his eyes were set apart by the distance the plane flew between successive pictures.

Alice In Wonderland (1937 model), *hearing that a milk bottle, in the hands of modern Aladdins, can be turned into threads of pure glass for weaving into cloth, decides upon a personal investigation and, as pictured here, visits the new reasearch laboratory of the Owens-Illinois Glass Company's Fiberglas division in Newark, Ohio. There she met the men who discovered the process by which insulation and textile glass is now produced in America and Europe.*



OWENS-ILLINOIS DEDICATES NEW LABORATORY FOR FIBRE GLASS RESEARCH

Another milestone in the history of glass making was marked last month when more than 200 scientists, educators and industrialists assembled at Newark, O., to dedicate with Owens-Illinois a new laboratory devoted to research and the development of fibre glass.

Not that fibrous glass is entirely new. Some few thousand years ago, it was made by the Phoenicians. In a more modern time, some European countries, notably Germany, produced it on a limited scale. And it was just three years ago, almost to a day, that Owens-Illinois discovered what has developed since into both a method of high speed production and a fibrous glass so far superior to anything ever previously known that it is now becoming one of the country's major industrial materials.

The most outstanding feature of the laboratory is not the building but its men. Or better, not so much the men as their spirit and attitude. Many organizations boast of an *espirit de corps;* here it really exists. A group of men comparatively young, so completely captivated by the fascination of their job; a job consisting of almost unlimited exploration into almost virgin territory, which week by week yields up another and yet another of its seemingly unlimited secrets. No wonder that time has no meaning for these tireless enthusiasts, many of whom say they return night after night to their laboratory work for the pure pleasure it gives them. This was one of the two most outstanding features noted by everyone.

The other outstanding feature was the way in which the Owens-Illinois Glass Company broke down all the barriers that have so long kept the manufacture of fibrous glass a secret or a near secret. The factory was yours to inspect, from cellar to garret—and what a fac-

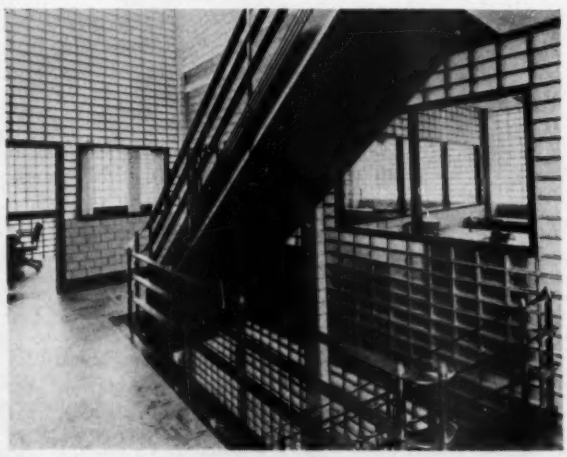
tory it is! The research staff was well nigh decimated to afford a corps of guides competent to answer any kind of question, lay or technical, concerning the process. If, after a three hour inspection tour, anyone failed to understand at least the rudiments of the process, he had no one but himself to blame.

Elsewhere in this issue of THE GLASS INDUSTRY are views of fibre glass making taken at the Corning Glass Works. Since Corning operates under Owens' licenses, the machinery for making fibre is quite similar at either plant—turn to following pages to see the highlights of fibre glass making equipment.

The dedication ceremonies were impressive. The day began with a breakfast, a uniting of old friends and familiar faces. Notable was the table service—glass plates, glass cups, glass saucers, everything of glass. It was the contribution of A. H. Heisey & Company, local manufacturers. Harold Boeschenstein, General Manager of the Owens-Illinois Company, made a short address, in the course of which he defined a research engineer as "a man who happens to be present when something unusual occurs, and who knows what to do with it." This was particularly à propos of the "discovery" of the Owens fibrous glass process, which resulted from the experiment of a man who was trying to color glass block by a spraying process. James Slayter, Director of Fibre Products Research, recounted the history of fibrous glass from earliest times and concluded with the statement that 95 per cent of all the fibrous glass in the world is made by the Owens process. He quoted Dante: "All can be spun, even the sands of the sea."

After breakfast, the entire party embarked by bus and automobile for a tour of the Research Laboratory. An impressive procession, five large busses and a fleet of 40 or 50 private cars.

The ceremonies of dedication took place in a large room on the ground floor of the laboratory building—President William E. Levis welcomed each and all, and expressed the appreciation of the Owens-Illinois Glass Company that so many had come from so many far parts of the country. He introduced Dr. A. C. Willard, President of the University of Illinois, who delivered the one formal address of the day. At its conclusion,



A striking study in glass. This photograph, taken on the second floor of the new laboratory of the Owen-Illinois Glass Company at Newark, Ohio, shows the trend to "open up" exterior walls and inside partitions to obtain more light.

Miles of silk-like fibers of glass greeted Alice In Wonderland as she visited the warper department where she saw innumerable spools of yarn, fresh from the tank of melted marbles, being combined to produce wide beams. From this warper the wide beam of material is taken to a weaving machine or loom to be fabricated into cloth of predetermined width, and to be used for filters—perhaps curtains, drapes or what's-your-pleasure.

S. T. McGiveran, Director of Advertising, unveiled two large plaques upon which were appropriate inscriptions. Kleig lights flared, flashlights exploded, movie men ground their machines, and the formal ceremony of dedication was concluded.

Then a trip through the factory to see the actual process of fibre glass making. It is impressive to think that it was in this same building that the first Owens bottle machine was installed in May, 1905. Twenty-nine years later, under the same roof, the first glass fibre machine was put in operation, in November, 1934.

The following were among the glass men present at the dedication ceremonies: Eugene C. Sullivan, H. C. Bates, and A. E. Marshall, Corning Glass Works; F. C. Flint, Hazel-Atlas Glass Co.; Ross Purdy, American Ceramic Society; E. Ward Tillotson, Mellon Institute of Industrial Research; E. Wilson Heisey and T. Clarence Heisey, A. H. Heisey & Company; Howard Miller, General Electric Company; Frank H. Adams, Surface Combustion Corporation; A. C. Willard and C. W. Parmelee, University of Illinois; Nelson W. Taylor, Pennsylvania State College; Arthur S. Watts and James D. Withrow, Ohio State University; John T. Ogden, *The Glass Industry;* Earl P. Stevenson, Arthur D. Little, Inc.; Hans Heye, *Action Gesellschaft der Gerresheimer Glasshuttgewerbe;* Albert S. Low, The Austin Company; and forty-three members of the Owens-Illinois Glass Company, including president William R. Levis and Harold Boeschenstein, general manager.

GLASS FIBRES FOR GLASS HOUSE NEEDS

Fibre glass has often appeared in the limelight of late as a new material that can be used for many industrial purposes—for cable insulation, for textiles, rope and even dress goods materials. Even closer to the glassman than these general purpose applications are some interesting "discoveries" for its use in glass houses.

Strictly speaking, the word "discovery" is correctly used only as it applies to this country. Applications similar to those to be discussed here briefly, and many others, have been in use abroad for many years. Only the large scale manufacture of glass fibre in this country now makes its advantages available.

Glass fibres of two general types are now produced: long textile fibres one-quarter of one thousandth in diameter, and shorter insulating wool fibres about four-tenths of one thousandth in diameter. With the glass fibres, as in other insulation, the insulating effect is secured through the trapping of numerous very, very small cells of air between fibres. In technical terms the fibrous insulation has a conductivity of .27 Btu per square foot per hour per inch of thickness per degree of Fahrenheit difference in temperature between the hot and cold sides. In non-technical terms, this means that the glass fibre product is a good insulating material.

Illustrated is a long strip of wool with an asphalted paper back. This strip is of a type that would be applied to a regular wool job such as wall or ceiling insulation. One very interesting feature is the matted arrangement of the long fibres so that they hold together satisfactorily for such a strip of insulation. A side light in the manufacture of the fibres is the handling of the wool with a pitch fork. In another illustration, one of the boys is pitching cullet. Actually, in charging the tank with cullet, a pitch fork is used and glass men are rather intrigued with this operation. In the next figure we have a view of the unloading end of the conveyor showing the product ready for packing.

From a glass man's standpoint, the storage of this material is of great interest because of the bulk. A very large proportion of the contents of packages is air, and for this reason warehousing requires a great deal of space.

A very economical building structure has been developed by using a steel frame work placing corrugated iron on the outside, and 4" of fibre insulation between this outer sheet and a light sheet of corrugated iron on the inside. The advantage of this construction lies in low investment for building, fireproof construction and a high degree of comfort due to low heat loss and remarkable coolness when the summer sun is blistering hot. Some of these buildings have been constructed in Corning and more are to be erected this year and they have been quite satisfactory. In many glass plants expensive brick and concrete construction have been a handicap because they are not readily altered to meet new needs, and herein lies another advantage of the new construction because it gives flexibility and low cost of alteration which is sorely needed by a developing industry.

One interesting, more or less unofficial, application of the bulk insulation came during a hot repair to the front end of a tank. Because the back end structure was badly worn the back end temperature was kept quite high during the repair, resulting in hot working conditions for the men. During the repair the top of the refiner glass was frozen with water and when the end wall was opened, insulation was heaped on the semi-rigid glass surface forming an insulated shield which shielded the men from the direct radiation due to the fires in the back end of the tank. The fibres next to the back end gradually fused down and more wool was added to shade the front end wall opening. As a result of this procedure, a very difficult job was declared by the men to be unusually cool for a hot repair. Glass contamination was not noticeable and had there been any normal running of glass from the front end the contamination would probably have been corrected because the composition of the fibres is very close to that of the ordinary soda lime glass. While this use in a way was a freak application, it was very effective.

The fibres start to soften at about 1000° F and their use at over 900° F is not recommended. Bulk insulation is used for insulating portions of lehrs, ovens and kilns where the temperature is under 900° F with excellent results. At lower temperatures the fibres are packed very loosely, while at higher temperatures they are packed in tighter. The mat of fibres is very light in weight and supporting structures need not be costly. Another minor use around lehrs and like equipment is stuffing a handful or two of the fibres in openings around gas burners.

Teaser offices, instrument cabinets, offices or shops near lehrs, shops over lehrs and many other plant applications of insulation with outside ventilation offer opportunities to better use of space that is often lost in a plant. Insulation of packing room roofs, particularly low ones, is another use for comfort and quqality, both summer and winter. In one Corning installation it was necessary to build a room above a furnace, insulation provided conditions that permitted working in the room when the temperature on the stairway leading to the room was as high as 140° F. While this is unusual it does show what can be done by combining insulation with ventilation. Portable shields using three or four inches of wool between hardware cloth or light sheet metal with a metal frame edging have been very helpful in cooling off some of the hot places where men must work near a hot refractory surface. Shields of this type help in the charging of tanks. They are more effective than water shields without the trouble of pipes, drains and the tendency of water to blow around.

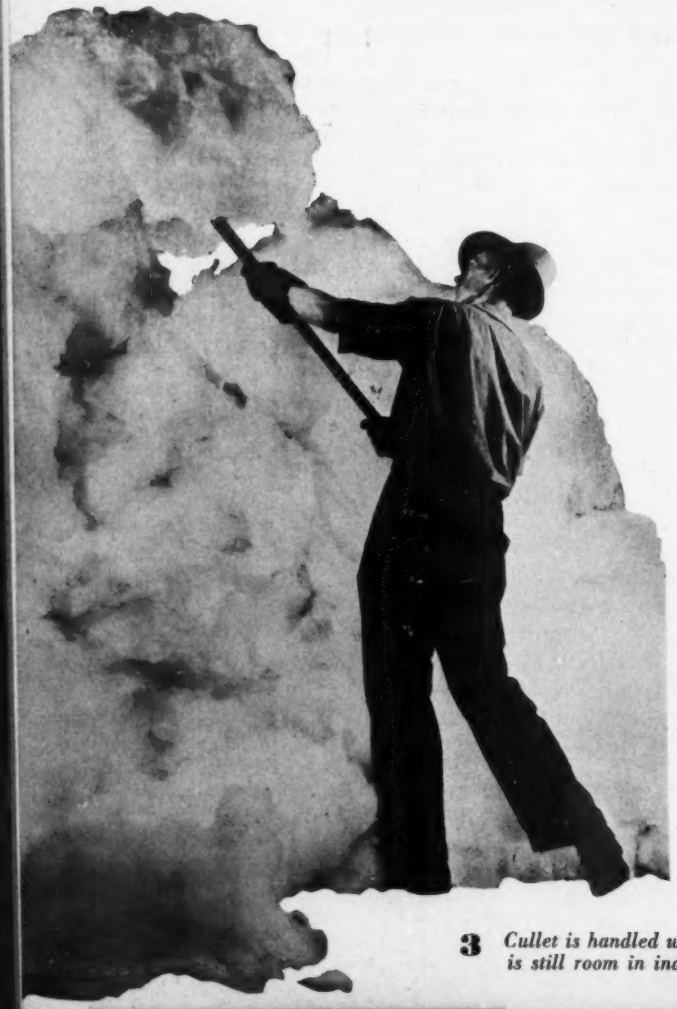
A cement has been developed for boiler, regenerator, lehr and like uses. While light in weight the material effectively seals and gives insulation equal to or better than ordinary materials, thickness for thickness. A very flexible type of blanket insulation consists of wool stitched to ordinary paper, asbestos paper, flame proof muslin, etc., for insulation of large low temperature ducts and pipes to keep heat in or out as desired. A variation can be made using chicken wire to add permanence. These products can be trimmed and formed to suit during the installation and the weight is so low that special supports are seldom necessary.

Blankets with chicken wire and/or metal lath confining

CANDID CAMERA STUD

1 *The charging port of the tank furnace where raw materials are melted for conversion into fibre glass.*

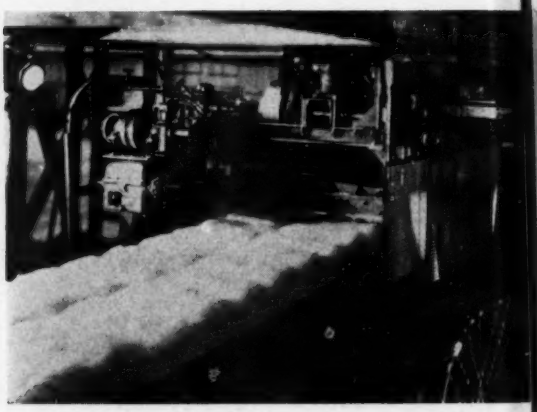
2 *Shooting the temperature at the charging port by means of an optical pyrometer.*



3 *Cullet is handled with a pitchfork, proving that there is still room in industry for the ambitious farm boy.*

4 *Here we see the glass emerging for the first time in the form of wool.*

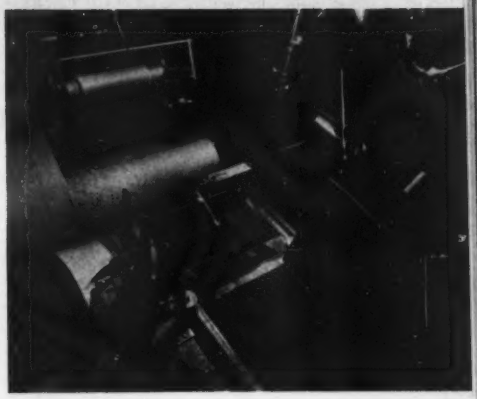
5 *The machine in this picture is getting the wool ready t be shaped into bats.*



6 *The wool is passed under a roller and weighted belt which compress it to proper thickness.*

FIBRE GLASS MAKING

Photos by Robert Yarnall Ritchie



7 *A strip nine feet long and 15 inches wide in which the fibre has been adhered to an asphalt paper. There are several types of these backings (as see photo 9), depending upon the service to which the insulation will be put.*

10 *Glass wool being spun into threads. In this view it appears to come from nowhere, which is due to the minute size of the fibre and to the fact that it is a transparent material. Note also the gas flame which heats the threads continuously.*

11 *The first step in making glass cloth. This machine is a braider, converting the yarn into flexible threads from which the textile is later woven.*

8 *The wool is packed into paper bags for storage. Because of the great amount of airspace, storage is a problem.*

12 *Not a textile mill, but a scene at the Corning Glass Works. Here the fibres are given a twist. In weaving, standard looms are used throughout.*

9 *Sewing the wool in the form of paper covered batting called a "blanket."*

13 *A glass curtain covering a window of glass block.*

wool are being used successfully for boiler, hot water heater, steam purifier and other installations. While made in standard sections, normally 2′ x 8′, they can be formed and well fitted around various corners, pipes and projections. A variation of thickness and weights is provided to cope with various temperatures involved. Insulating cement may be applied to the metal mesh to give the job a finished appearance. Such blankets are very useful for lehrs and kilns in case insulation is needed at some times, and not needed at other times.

While the above gives some of the applications, there are in the glass industry many other uses for insulation not discussed herein. Glass fibres, while rather new in this country, have been used for many years abroad, and their merits have been definitely proven. They are now available in this country and their advantages may be enjoyed.

ARTIFICIAL ILLUMINATION OF GLASS BLOCKS

A paper presented before the 31st Annual Convention of the Illuminating Engineering Society last month by C. S. Woodside, Westinghouse Lamp Division, offered technical data for the use of the architect or builder contemplating the installation of glass blocks. The author notes that most domestic blocks currently manufactured are of the hollow, partial-vacuum type, which are non-load-bearing, but have sufficient strength to sustain their own weight for any reasonable height. Purdue University tests have indicated a compressive strength of over 250 lbs. per sq. in., and the wind pressure resistance of a glass block wall is very much greater than a glazed window of similar size. It is also stated that, in general, glass blocks will eliminate 55 per cent of solar heat, as against 20 per cent by glazed steel sash under similar conditions.

The transmission of light through glass blocks is largely dependent upon the direction of the light rays and the design of the blocks. The width of the joints, the color of the mortar, and the thickness of the blocks are also contributing factors. Clear blocks will transmit from 50 to 75 per cent of the incident light, and configurated blocks from 40 to 75 per cent.

If the glass block wall is to serve as a primary source of illumination, it will be quite similar in characteristics to a steel-sash window glazed with a configurated glass. It is strongly emphasized that such a wall alone will not provide a desirable distribution of illumination, and that it should be used only with other lighting. However, where a glass block wall is used merely as an element of decoration, the brightness levels should naturally be low, and the resulting illumination can be ignored in calculating the lighting in a room.

When a glass block wall is to be illuminated, the construction will usually permit a small space between the glass wall and a solid partition to allow room for the lighting units. There may be show window or paracyl reflectors located in the recess above the top course of blocks, or individual reflectors located behind each block. Since a white background gives a flat, uninteresting appearance to the wall, other backgrounds were investigated, the best consisting of coarse metallic particles scattered over a freshly painted surface. The sparkling metallic background adds life to the glass.

While glass blocks are used for their excellent insulating qualities, to insure privacy, or as elements of decoration, the material used is glass and should appear as such when it is to be lived with. Lighting which tends to flatten out the glass and obscure the design is not pleasing and should be avoided. Individual points of relatively high brightness can be tolerated, although the general brightness of the wall should be low because of the large areas involved.

MILLIONTHS MEASURED IN FORD GLASS PLANT

Deviations of one-millionth of an inch in material under manufacture are measured instantly, in the shop, with a new "profilometer" developed for the glass plant of the Ford Motor Co. This instrument, the only one of its kind in existence, brings millionth-of-an-inch precision out of the laboratory and into the production line. The unprecedented speed and accuracy of the device, which measures units so small 3,000 of them would be required to equal the size of a human hair, is arousing wide interest among scientists. While the profilometer now is being used to check the smoothness of safety glass used in Ford V-8 cars and trucks, company engineers believe it can be used to insure almost unbelievable accuracy in scores of other manufacturing processes.

The instrument operates on some of the principles used in radio, and is not impressive in appearance. It consists of a small metal box attached by a five-wired electric cable to an amplifying cabinet. There is a dial on top of the small metal box, and a diamond-tipped needle in the bottom. As the box is pushed across the surface to be measured, the needle follows the invisible contours in it. This causes variations in the electric current, which are amplified in the larger cabinet, and returned to the dial, where an instantaneous reading appears in terms of millionths of an inch.

PLATE AND WINDOW GLASS PRODUCTION

The production of polished plate glass by member companies of the Plate Manufacturers of America in Sept., 1937, was 16,479,144 square feet as compared to 17,898,064 square feet in August and 19,552,775 square feet produced in Sept., 1936. This makes a total of 156,299,562 square feet produced during the first nine months of 1937.

The Window Glass Manufacturers' Association reports that window glass production during September was 1,212,374 boxes, which represents 74.7 per cent of industry capacity. The total production for the nine months of 1937 amounted to 10,344,384 boxes, which represents 70.8 per cent of capacity.

A building industry conference to analyze the causes of the slowing down of residential building and to suggest means for stimulating activity in this field will be held either in the latter part of November or the early part of December by the Chamber of Commerce of the United States, according to George H. Davis, president.

More than 1,000 square feet of exhibit space in the Homes and Gardens Building of the 1939 Golden Gate International Exposition on San Francisco Bay have been taken by the Pittsburgh Plate Glass Co. Carrara structural glass, glass blocks, and many novel uses of glass for interior and exterior finishing will be shown.

INDUSTRIAL PROPANE AS A GLASS PLANT FUEL

Shipped as a liquid and used as a gas, the special properties of industrial propane solve many glass plant heating problems.*

Satisfactory fuels for special heating requirements are usually available in many localities, but sometimes are not satisfactory because of the cost factor. Today these needs are being filled economically by the liquefied gas product known as industrial propane. Propane utilization is a comparatively new development in the glass industry, but its advantages under certain conditions have been demonstrated in several installations during the last few years. Certain properties of this product are, of course, responsible for the performance record achieved by propane.

If the basic hydrocarbon compounds found in oil and natural gas are arranged in order of increasing density in the gaseous state, an interesting variation of other important physical and chemical properties is found in the same order. The lighter gases have the lowest critical temperatures, the highest vapor pressures, the highest heating value in Btu per pound, and the lowest heating value in Btu per gallon as liquid, or Btu per cubic foot as gas. At the low density end of the list is methane, which cannot be liquefied practically at room temperatures. At the other end of the list are the heavy fuel oils, which cannot be gassified except at very high temperatures.

Between these two extremes are a series of hydrocarbon compounds, some normally liquid and some normally gaseous. Two of these compounds, butane and propane, are of particular interest because, although normally gaseous, they may be liquefied at ordinary temperatures and moderate pressures. Of the two, propane is of greater interest as a glass plant fuel because it has the higher vapor pressure. This permits vaporization under ordinary conditions without the application of heat, and also accomplishes certain savings through the use of higher distribution pressures. Average properties of industrial propane are shown in Table I.

These properties reveal why propane provides an economical true gas fuel for localities not served by natural gas lines and in which the oil or artificial gas supply is either not satisfactory for specific applications or too expensive. First, propane is a very concentrated fuel, having a heating value of 91,800 Btu per gallon of liquid, or 2,537 Btu per cubic foot of gas, after vaporization. Second, propane can be handled, shipped and stored as a liquid under pressure, the pressure being the vapor pressure at the temperature of the liquid. For instance, at 70°F the pressure is about 122 lbs. per sq. in., gauge.

Table I—Average Properties of Industrial Propane

Vapor Pressure, Lb. per sq. in., gauge:	
at 70° F.	122
at 90° F.	165
at 100° F.	190
at 105° F.	204
at 130° F.	282
Initial Boiling Point, Deg. F. at 14.7 lb./sq.in., abs	—51
Weight per Gallon Liquid, Lb. at 60° F.	4.26
Dew Point, Deg. F. at 14.7 lb./sq.in., abs.	—45
Specific Heat of Liquid, Btu/lb./deg.F. at 60° F.	0.587
Cu. Ft. Gas (30″ Hg.) per Gallon Liquid at 60° F.	36.18
Specific Gravity Gas (Air = 1) at 60° F., 30″ Hg.	1.53
Ignition Temp. in Air, Deg. F.	920-1,020
Maximum Flame Temp. in Air, Deg. F.	3,600
Per Cent Gas in Air for Max. Flame Temp.	4.2-4.4
Required for Complete Combustion:	
Cu. Ft. O_2 per Cu. Ft. Gas	4.9
Cu. Ft. Air per Cu. Ft. Gas	23.4
Products of Complete Combustion:	
Cu. Ft. CO_2 per Cu. Ft. Gas	3.0
Cu. Ft. H_2O per Cu. Ft. Gas	3.8
Cu. Ft. N_2 per Cu. Ft. Gas	18.5
Latent Heat of Vaporization at Boiling Point:	
Btu per Pound	184
Btu per Gallon	784
Total Heating Values (after vaporization):	
Btu per Cu. Ft.	2,537
Btu per Pound	21,570
Btu per Gallon	91,800

Propane is shipped generally in tank cars holding about 9,600 gallons or, in certain localities, is delivered by tank trucks. For storage of tank-car lots, storage tanks of from 12,000 to 30,000 water gallons capacity are used, the number and size of the tanks for the storage system being determined by the amount of propane used, the time required to receive tank-car shipments and the plant gas-load factor. Storage tanks located above ground on concrete foundations, as shown in Fig. 1, are preferred, although underground tanks may also be used to satisfy special local conditions. Tank cars are unloaded into the storage system by pumping or by a differential of pressure.

Unless the demand for gas is very large, industrial propane is withdrawn from the storage tank as a gas and passed through regulators to secure pressure control, vaporization taking place within the tank. There is, however, a definite limit to the amount of gas that will be vaporized in a storage tank, and a vaporizer, which is simply a heat exchanger utilizing hot water or steam, may be required under certain conditions. The factors

Fig. 1. *An* 18,000 *gallon propane storage tank at the Whitall-Tatum Co., Millville, N. J.*

*For illustrations and data on industrial propane and its applications, GLASS INDUSTRY acknowledges its indebtedness to the Phillips Petroleum Co., The Whitall-Tatum Co., The Hartford-Empire Co., The Surface Combusion Corp. and The Toledo Engineering Co.

which determine the necessity for a vaporizer are maximum demand for gas, size of storage tank, location of storage tank, minimum amount of liquefied gas carried in storage tank, climate, and plant gas pressure desired. Industrial propane is forced from the storage tank to the vaporizer as a liquid by its own vapor pressure, this being accomplished by arranging the opening of the outlet pipe in the tank so that it is always below the level of the liquid.

Since the storage system is always at a comparatively high pressure, the distribution system for propane gas can be very flexible, furnishing either high-pressure or low-pressure gas through simple regulators as required, and without any necessity for boosters or pumps. The pipe lines for industrial propane distribution are much smaller than those for other gaseous fuels on account of the high thermal value of propane and the higher pressure at which it is distributed.

In addition to its use as a primary fuel, propane is also being used in some large plants to enrich other low heating-value gases, such as coke oven or blast furnace gas. The latter application provides a satisfactory fuel for luminous-flame installations, now becoming more and more popular for melting and annealing purposes. Of course, undiluted propane may also be used alone for luminous-flame heating, if desired.

In general, the combustion systems and burners used for other gas fuels are satisfactory for the burning of industrial propane, with slight changes to produce the required fuel-air proportion for proper combustion. The system commonly used includes: 1. nozzle mixing burners; 2. atmospheric burners; 3. low-pressure premix burners, and 4. high-pressure premix burners.

Nozzle Mixing Burners

In its crudest form the nozzle mixing burner is simply a stream of raw gas issuing into the open air from the end of a pipe and burning with a yellow flame, drawing combustion air from the surrounding atmosphere. The common glass-tank firing port is an example of such an arrangement, in which the gas is directed into a stream of pre-heated air and combustion originates at the point of mixing. It is difficult to burn propane, as well as other gases, economically in such a system, however, and special burners have been developed to give better control of the fuel and combustion air. Fig. 2 illustrates diagrammatically a nozzle-mixing type of burner used with propane and designed to inject the combustion air in the form of a blanket. The fuel burns with a luminous flame as it mixes with the air blanket, thus producing a diffuse flame and non-localized heating. Flame control is secured by injecting a certain volume of "control gas," usually products of combustion.

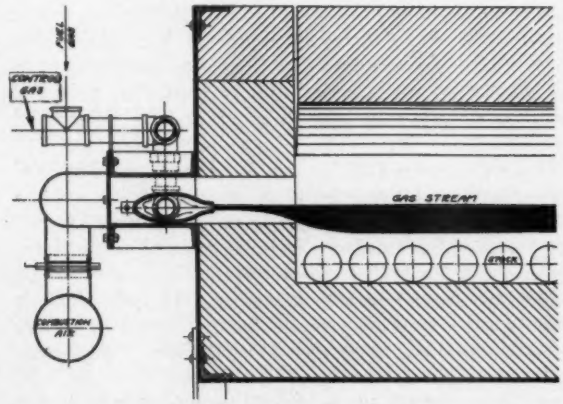


Fig. 2. Diagrammatic illustration of special nozzle mixing burner producing a luminous flame with propane gas.

Atmospheric Burners

In the atmospheric burner the kinetic energy of the gas stream, issuing from an orifice at relatively low pressure, is utilized to inspirate part of the air required for combustion. This partial pre-mixture issues from a port or series of ports and burns with a relatively short blue flame. Familiar examples are the Bunsen burner and the domestic cooking-stove burner. Obviously such burners cannot be applied to inclosed furnaces, except where ventilation of the furnace is sufficient to supply the secondary air for combustion. For the combustion of propane in glass plant applications the atmospheric burner is not important, because it is much less efficient than the total premix types described below.

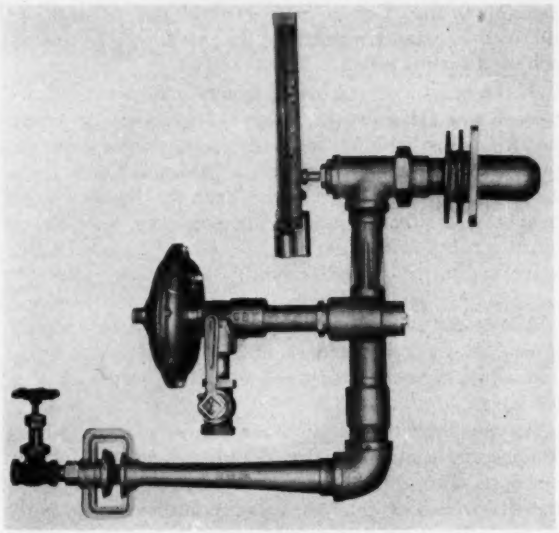
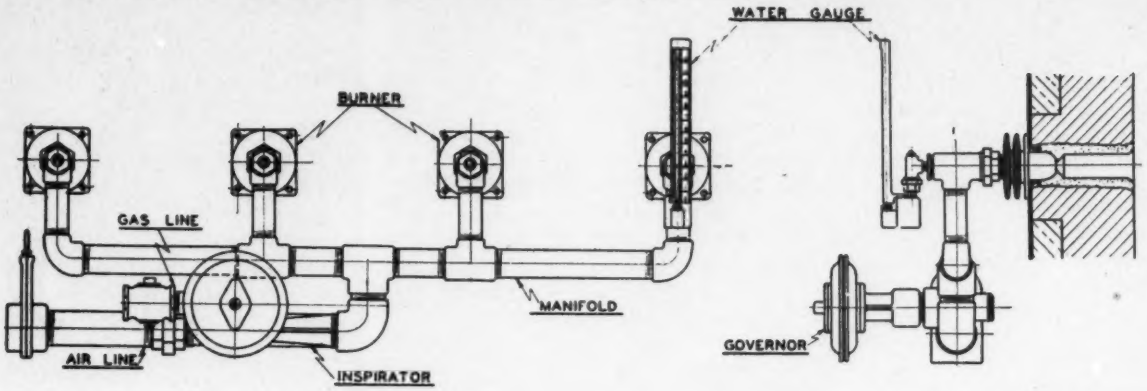


Fig. 3. Low-pressure premix burner for propane. High-pressure air inspirator shown at the bottom, gas inspirator in vertical pipe.

Low-pressure Premix Burners

When air and gas are both applied under pressure, they can be premixed in the proportions required for complete combustion. With the gas at low pressure the incoming combustion air, at a relatively high pressure, is used to inspirate the required volume of gas. This arrangement has been found very satisfactory for the combustion of propane, but the same care must be used in the design of the port as with other fuels. A burner of the low-pressure premix type is illustrated in Fig. 3. This burner has an automatic proportioning system, in which the rate of combustion is controlled by a single valve, usually in the air line. In a typical system of this type, combustion air is supplied at from 8 to 32 ounces pressure, and fuel gas at 2 or 3 ounces. High-pressure air may be passed through an orifice into the bell mouth

Fig. 4. Diagram showing low-pressure premix equipment with manifold and four burners.



of a venturi to inspirate two to five parts of atmospheric air. The combustion air, at about 2 lb. pressure, then passes through the low-pressure proportional inspirator into which the gas is drawn through a suitable orifice, the gas pressure being controlled by a regulator. Fig. 4 shows the application of such a system, in which the gas-air mix is supplied through a manifold to four burners.

High-pressure Premix Burners

In this system fuel gas at sufficient pressure is used to inspirate the necessary combustion air from the surrounding atmosphere, a typical inspirator being shown in Fig. 5. The high-pressure gas issues from an orifice or spud into the open end of a bell-mouth venturi tube, drawing in air through the annular opening around the orifice. Since the quantity of air in the resultant mixture depends on the kinetic energy of the gas stream, it follows that the gas pressures required for this system of mixing increase with the air-gas ratio. Artificial gas with a heating value of about 550 Btu. per cu. ft. is usually supplied at from 5 to 10 lb. per sq. in.; natural gas, having 1,000 Btu per cu. ft., requires from 10 to 20 lb. per sq. in. pressure, and propane, with a heating value of approximately 2,500 Btu per cu. ft., is usually supplied to high-pressure proportioning mixers at pressures around 25 to 30 lb. per sq. in.

Any complete premixing or partial premixing system is well adapted for the utilization of propane, with practically no changes. Such devices provide for accurate and quick control of flame characteristics and also provide higher manifold pressures than are normally furnished by other types of gas-burning systems.

In glass plants where natural or artificial gas is not available at attractive rates, where economies can be effected by the enrichment of low heating-value gases, and in cases were these gases are not satisfactory for lehr or feeder firing, industrial propane offers not only economies but also a higher quality product.

At the Whitall-Tatum plant, Millville, N. J., some very interesting applications of propane as a substitute for fuel oil have recently been made. This company has for many years used fuel oil as the heating medium for forehearths and lehrs and has been able to secure quite satisfactory results through the application of automatic temperature control. However, the use of propane gas was instituted in order to secure the better heat control and distribution inherent in gas-fired equipment. The Hartford-Empire Co. cooperated by developing a method for

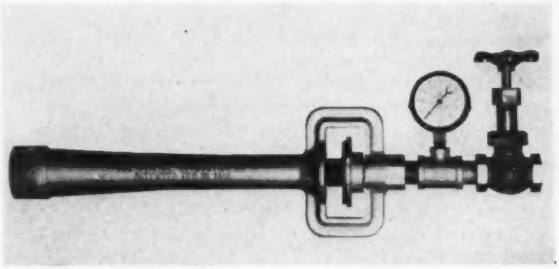


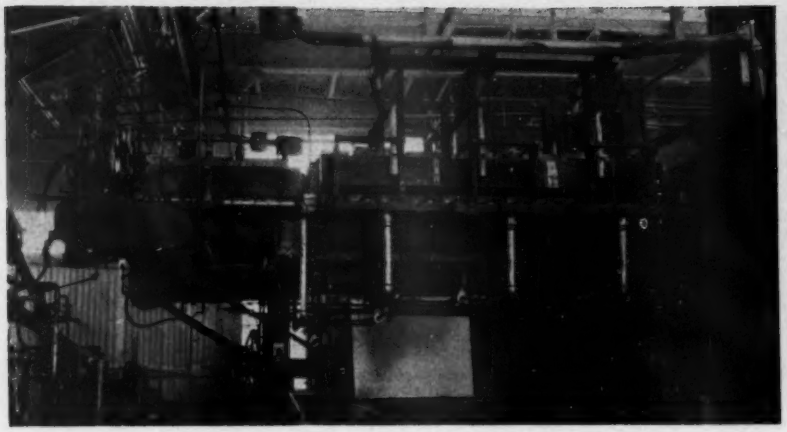
Fig. 5. High-pressure inspirator for high-pressure gas and atmospheric air. Used in connection with a manifold distributing the mixture to one or more burners or the tunnel, impact or flame-retarding type.

utilizing propane in place of fuel oil. Data already secured seems to indicate a lower fuel cost in the later type of feeder and forehearth, improved operating efficiency and higher quality ware.

One of the Hartford-Empire forehearths arranged for propane heating is illustrated in Fig. 6. The forehearth temperature is controlled in three zones, each zone manifold supplying a number of small burners which fire perpendicular to the glass flow. The system is the "low-pressure premix burner" type, previously described, in which the high-pressure air is taken through Foster regulators and passes to the high-pressure inspirator sets, where it induces from three to five parts of atmosphere air. The lower pressure air mixture from the high-pressure inspirators then goes to a low-pressure proportional inspirator, in which the air velocity induces the flow of the proper quantity of gas, and the final gas-air mirture is then piped to the burner manifolds.

The amount of heat delivered to each zone is controlled by simply turning the handwheel of the high-pressure air regulator for that particular zone, and it has been found that the system will often function properly for an entire shift without any change in the burner setting. The installation produces a greater quantity of acceptable ware than formerly not only because the operator has greater opportunity to watch all operations carefully, but also because of the continuously uniform glass conditions. As shown in Fig. 7, the mixing and control apparatus is usually located at the back end of the forehearth. It is stated that the installation requires only about one-quarter the amount of high-pressure air needed for fuel-oil burners.

Another propane application which has been found to produce good results economically is for heating direct-



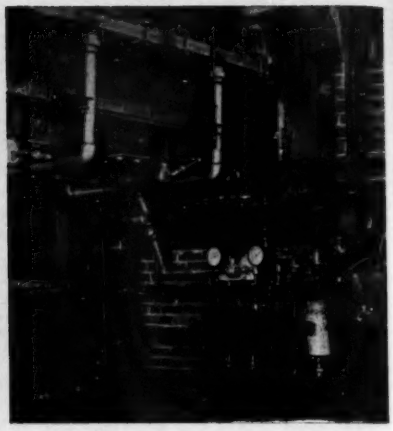


Fig. 6. Hartford-Empire forehearth at Whitall-Tatum heated by propane and using automatic proportioning equipment of the low-pressure premix type. Fig. 7. Propane mixing and control equipment at back end of Hartford-Empire forehearth.

fired lehrs. This type of equipment has been used in some places instead of indirect oil-fired lehrs or direct gas-fired lehrs. Indirect oil-fired lehrs have the handicap of higher installation and maintenance cost. Direct gas-fired lehrs depend for satisfactory operation on cheap natural gas with a low sulphur content.

With industrial propane, direct gas-fired lehrs can be used almost regardless of the plant's geographical location. Several lehrs of this type, manufactured by the Hartford-Empire Co., have been installed at Whitall-Tatum and other plants in the vicinity, where a suitable supply of natural gas is not available. These lehrs utilize propane with the high-pressure inspirator type of burner. The burner velocity circulates the hot products of combustion, maintaining uniform temperatures with a relatively high belt speed. Because of the very low sulphur content in propane, no bloom or discoloration of the ware results.

Other recent propane applications include heating of conveyors and turn-tables which carry ware from the forming machines to the lehrs, luminous-flame firing of glory holes, fire-finishing, lehr belt warming at the hot end of the lehr, and unit heaters for building space.

Propane is not now used to any great extent for melting, but it seems to have definite possibilities, especially for the melting of special glasses in day tanks where colors are unfavorably affected by sulphur or ash in other types of fuel. It is also used to enrich low heating-value gases for melting furnaces, the resulting mixture being burned in a special nozzle mixing type of burner that produces a luminous flame.

When considering the application of propane in plants now using other fuels, several factors deserve attention. As far as the piping system is concerned, any system now handling other gas fuel satisfactorily will be amply large for propane, because the capacity of a given piping system, for the same line pressure and pressure drop, is increased 162 per cent on a Btu basis when propane is substituted for natural gas, and 230 per cent as compared to artificial gas. Burners of the automatic-proportioning type, now operating on natural gas, can be converted to propane with little change. Artificial gas burners require some change and, of course, all burners formerly used with oil or producer gas must be replaced with suitable equipment.

The decision to adopt propane as a fuel should be based on operating and economic considerations. Aside from the relative cost of the present and proposed fuels per unit of heating value, other economic factors include possible improvements in products, labor saving, and reduction in maintenance cost on furnace equipment. Complete data accumulated from a number of fuel conversions, involving all types of industrial heating processes and alternate fuels, are now available.

● *Side view of Hartford-Empire glass lehr installed at Whitall-Tatum. Burner equipment consists of Selas high pressure inspirators firing into a tube placed across the furnace with two burners from this tube at right angles to the tube itself firing in a longitudinal direction toward the front of the lehr.*

GLASS NEWS FROM ABROAD

Argentina

Up to the present the Argentine window glass consumption depended entirely on foreign imports. Now, the Pilkington Brothers Co., an Argentinian glass manufacturing company, is cooperating with French producers to establish a home industry. The Saint Gobain group and Pilkington have founded the Vidrieria Argentinas for the manufacture of window glass. It is anticipated that the establishment of the new industry will substantially affect foreign imports.

Australia

Negotiations are pending between the representatives of the Australian crystal glass industry and the government of the Dominion for reducing the import quota from 75 to 50 per cent in favor of domestic producers. The industry contends that as a consequence of the foreign competition Australian factories have taken more than 200 workers off the payrolls.

Belgium

Hostilities in China reflect on the Belgian glass industry. Although the price war which had been raging in the domestic market has recently come to a standstill, business conditions remain unsatisfactory because of the foreign situation. The Union des Verreries Mecaniques, for instance, was forced to close its factory at Jemages.

Czechoslovakia

The former glass works of the Haida (Bohemia) Glassworkers' Training School, a municipal concern, is undergoing complete reconstruction. The works have been idle for several years. Negotiations are now, however, taking place between the Haida City Corporation and the Stepanek Bros. Glass Refineries, who propose to lease the premises for the production of flint glass.

Denmark

A new glass manufacturing firm, the Dansk Glas Og Kapelininidustri, has acquired a site at Glostrup, near Copenhagen, for the erection of a large factory, designed to produce a new type of glass container.

Italy

It is by no means an easy task to build a new glass factory in Italy. For, in six cases out of seven, the government will forbid it. During these last months, the authorities have received seven applications for permission to extend the glass goods industry. One, for a factory to produce 300,000 kilograms of goods per annum, was granted to the S. A. Produzione Esportazione Conterie Costantini Vistosi Camozzi of Murano near Venice. The remaining six applications were refused as "not essential to the economy of the corporative state."

The synthetic glass factories of Murano, near Venice, have recently installed the first modern electric furnaces in the Italian glass industry. The majority of the industry is still using charcoal, or highly inflammable "splint" coal as fuel. Burning is accomplished either directly in the furnace or by a coking process. The Italian producer uses on an average of from 0.7 to 1.0 tons of coal and 0.5 to 0.7 tons of naphtha for a ton of glass.

The chief raw material, silicon sand, was, until recently, imported from Belgium and France. Italian sand was considered suitable for only the cheapest lines of glass goods. Now, new large deposits have been found in Italy, which, owing to their small iron oxide content, are not inferior to the imported material. The Istria deposit contains only 0.007 to 0.001 per cent of iron oxide. Of the chemicals used in the glass industry, Italy can provide lime, soda, boric acid, borax and feldspar. Magnesium, potash and sodium, however, must be imported.

Japan

Following the recent official failure to bring about an accord in the glass trade, the Department of Commerce and Industry is now expected to present a plan for a compromise between the manufacturers and exporters. It is thought possible in some quarters that the authorities will eventually be obliged to take compulsory measures on the strength of Article 9 of the Export Associations Law. The present deadlock is due to the difference of opinion with regard to the allotment of export quotas. The manufacturers demand the right to handle the overseas sales of 70 per cent of their total export production. The exporters contend that with that much placed in the manufacturers' hands, the latter would be tempted to cutthroat competition among themselves, the more so because the quotas set for each concern are calculated on the basis of the value of previous export production, and not on a quantity basis.

The Asahi Glass Company has drawn up plans for a new factory at Tsurumi, near Yokohama. The plant is to produce special glass for photographic dry plates, at the annual rate of 200,000 cases. Construction works, which will be started late this fall, are scheduled to be completed in April, 1938. Tentative manufacture of thin glass for dry plate in one of Asahi's plate glass plants has been very encouraging, it is reported. It is believed that the firm will develop this line in close cooperation with Japan's leading dry plate manufacturing concern. Although Japanese-made dry plates are now an important export article, the raw glass has been imported to a large extent.

The Nitto Shoji K.K. is marketing glass wool ranging in fineness from 10 to 15 microns.

Poland

The glass works of Zabkowicze, which were closed two years ago, were reopened the end of October.

The Polish Skiernewicer glass works have opened a subsidiary plant at Stargard, Poland. This company employs about 150 workers for the manufacture of bottles for the Polish Alcohol Monopoly. The program of the factory is reported to include the production of beer bottles and drinking glasses.

Sweden

A loan of 35,000 Kroner ($9,700) has been advanced by the Swedish Government to the A/B Eda Glass Factories. Chief products of the firm are glass and glass containers.

EQUIPMENT AND SUPPLIES

DRAKENFELD INTRODUCES NEW SQUEEGEE OILS

Two new squeegee oils, Drakolene and Drakosett, have just been placed on the market by B. F. Drakenfeld & Co., New York. Compounded with ingredients which permit the superposition of several prints without smudging, Drakosett is particularly adapted for multicolor printing, a short drying period being allowed between successive printing operations. Drakolene is used for single-print work.

In developing these new products the manufacturer has aimed to produce oils which can be mixed easily and used with all colors, so that even the soft white enamels can be fired quickly without producing any tinge of gray. The production of clean, sharp prints under all conditions has been another objective. Prints made with Drakolene or Drakosett dry in air in from three to four hours and can be dried rapidly by heating to 200 or 300 degrees, F., for a short time.

Other features of these new squeegee oils include, it is stated, elimination of blistering; minimum amount of preheating; no absorption of moistuure by oils or mixed colors; and operation economies resulting from reduction in cost and amount of oil required.

FOXBORO ADDS NEW THROTTLING CONTROLLER

A new throttling potentiometer controller (Model 4038), designed to provide close temperature regulation for heat-treating furnaces and similar applications, has been introduced by The Foxboro Co., Foxboro, Mass. The electrically-operated control system regulates the position of a throttling valve to maintain the flow of fuel required to hold the temperature constant within the throttling range. Thus, the upsetting effect of abrupt changes in fuel supply is avoided, and the temperature remains constant within a narrow control zone.

This type of temperature control is said to be particularly suitable for precise regulation of furnaces operating under fairly uniform conditions of loading, fuel pressure, B.t.u. value and the like, where a definite furnace temperature may be expected for each position of valve opening. While it does not provide control as completely independent of all furnace variables, the throttling control permits substantial economy for a large number of furnace applications. A simple manual reset is provided to compensate for such periodic changes in operating conditions as may occur.

● *Foxboro's new throttling controller.*

"BI-OPTICAL" PYROMETER

Pyrometer Instrument Co., New York, reports the development of a new Pyro bi-optical pyrometer. The new instrument is based on the use of light filters and color wedges which are transparent to a number of colors simultaneously. The instrument is said to be capable of measuring temperatures from 900-1900°C or 1700-3500°F simultaneously for both the "black body" and the "actual" temperature.

TAYLOR APPOINTS

Chas. Taylor Sons Co., Cincinnati, have given the Elgin-Butler Brick Co., Austin, Tex., the exclusive sales contract covering P. B. Sillimanite brick, shapes and cements, as well as Taylor refractory brick, for the states of Kansas, Oklahoma, Texas, Louisiana and Mississippi. A. J. Metzger, Taylor's former advertising manager, is director of research for Elgin-Butler and W. W. Miller is connected with the sales department. Robert P. Stevens, formerly with the Acme Brick Co., succeeds Mr. Metzger as advertising manager of Chas. Taylor Sons Co.

NEW DIESEL FOR SMALL POWER USERS

A new Fairbanks-Morse Diesel, the Model 42-E, has been developed to meet the demand of small power users for a heavy-duty, continuous-service stationary engine. It is available in two- and three-cylinder combinations with ratings of 60 and 90 horsepower at 450 r.p.m., and can be furnished for direct-connected, belt or electric generator drive.

With an 8¾-in bore and 10½-in. stroke, this Diesel is smaller and lighter than the F-M Model 32-E, but it embodies all of the proven features of the larger engines. It is small enough to be installed where space and head room are limited, and it is applicable for any power requirement within its horsepower ratings.

C. E. Noble has been placed in charge of the Pittsburgh office recently opened by the Pyrometer Service & Supply Corporation of Cleveland. Mr. Noble was formerly assistant metallurgist of the E. C. Atkins Co., Indianapolis.

Laclede-Christy Clay Products Co., St. Louis, have announced the appointment of Donald W. Ross as a member of its research division specializing in refractories for the glass industry.

The American Foundry Equipment Co., Mishawaka, Ind., will demonstrate the Wheelabrator method of airless abrasive blasting at the National Metal Exposition, Atlantic City, N. J., Oct. 18-22.

CATALOGS RECEIVED

Industrial Tire Handbook. B. F. Goodrich Co., Akron, Ohio. A new 30-page booklet telling how to "lower costs and speed up plant operations by using the proper rubber-tired wheels" on material handling equipment. Reports of actual tests occupy the major portion of the text.

Industrial Products Catalog. Johns-Manville, 22 East 40th St., New York. The new 1937-38 edition of this well-known 64-page book is out. Roofing, siding, electrical materials, industrial water lines, vent pipes, stacking, and packings and gaskets are among the subjects covered.

Duplex Power Pumps. Bulletin 6130. Fairbanks, Morse & Co., Chicago. Described are duplex power pumps for oil field service, fire protection and general service requiring pressures up to 800 pounds per square inch and capacities to 187 gallons per minute.

Pyrometers, Potentiometer and Millivoltmeter Types. Catalog No. 1102. Brown Instrument Co., Wayne and Roberts Aves., Philadelphia. A new catalog covering the complete line of potentiometer pyrometers, including the new Brown Electr-o-Line controllers and the Brown proportioning control system.

Display plans for the 16th Exposition of Chemical Industries, Grand Central Palace, New York, Dec. 6-11, are rapidly being advanced. Raw materials and chemical products, laboratory and plant equipment, and machinery essential to industries based on chemistry and chemical engineering will be shown. Of particular interest will be an exhibition of glass as a material for pipe lines.

The September, 1937, issue of *Sands, Clays and Minerals,* published in England, has been received. Among articles of interest are: "Preparation and Marketing of Coal," "A New Meter for Clays and Mineral Dusts and Its Applications," and "Some Facts About Borax and Boric Acid and Their Less Known Applications."

ACCIDENTS IN GLASS PLANTS

National Safety Council, Inc., reports that, while there were no greater number of accidents in the glass industry in 1936 as compared with 1935, the severity of accidents increased some 32 per cent. These results compare unfavorably with a decrease of one per cent in frequency and an increase of five per cent in severity for all industries. As far as glass plants are concerned, the average of 9.11 for frequency and 0.80 for severity are based on reports from 47 plants whose employees worked 80,536,000 man-hours during the year. For industry generally, the rates were 13.57 and 1.64, giving the glass industry a ranking of tenth in frequency and eighth in severity compared with 30 major industries.

The following table classifies the position of the various groups in the industry:

Classification	1935-1936 Change in Frequency	1935-1936 Change in Severity
Entire Industry	0.0	+32%
Glass Products	—5%	+39%
Flat Drawn Glass	+7%	+33%
Incandescent Lamps and Radio Tubes	+46%	+120%

An analysis of the circumstances involved in these injuries discloses the following facts:

1. Three occupations—maintenance and repair men, supervisors and technical employees, and operators of machinery and other equipment—had one-half of all the serious injuries.

2. Machinery was the most important agency of injury, being involved in one-third of all accidents. The agencies next in importance were elevators and hoisting apparatus, and vehicles.

3. "Caught in or between" describes the principal type of accident. Such accidents occurred most often when employees got their hands and fingers caught in moving parts of machinery. Injuries due to falling, sliding, and flying objects were also common and often occurred when employees were handling objects by hand or by hoists and cranes.

4. Hazardous conditions and unsafe methods of performing certain jobs were the principal mechanical causes of serious injuries. One employee, for example, died from injuries inflicted by falling glass, which fell from piles on a moving turn-table.

Improper guarding, such as lack of or removal of guards, was also an important mechanical cause of serious injuries. An inspector lost an eye when walking along a passageway near which chipping operations were being performed.

5. The principal personal cause of serious injuries was lack of knowledge or skill, followed by wrong attitudes on the part of employees. One employee, starting to grease certain parts on a new type of bottle machine, did not completely shut off all air pressure and as a result he lost most of the use of one hand.

Disregarding instructions to shut down machines when oiling, adjusting, and repairing is one of the most common indications of wrong attitude on the part of employees. An employee with seven years' experience lost a finger when he removed a guard on a machine and attempted to clean it while in motion.

MOSTLY PERSONAL . . . . . .

CRANDON JOINS HARTFORD-EMPIRE

The latest edition to the Hartford - Empire Co. organization is Albert Seabury Crandon, who started in Hartford early in October. Mr. Crandon was born in New Bedford, Mass., and graduated from the Worcester Polytechnic Institute, where he made both honorary fraternities, Tau Beta Pi and Sigma Xi. For two years following his graduation he was retained at Worcester Tech as instructor. Later he was in the employ of the American Bridge Co.

Mr. Crandon has had extensive experience in the glass business, having been with the American Window Glass Co. since 1923. He will be employed at the Hartford-Empire Co. under Dr. John C. Hostetter, head of the Development and Research Department, where he will devote special attention to furnaces and related problems in glass melting. He will be associated directly with Vergil Mulholland, who is well known as one of the leaders in this branch of the glass business.

CARNAHAN IS NEW H-A GENERAL MANAGER

John W. Carnahan has been appointed general factories manager of the Hazel-Atlas Glass Co., succeeding the late Samuel B. Bowman. Mr. Carnahan, who has been with Hazel-Atlas for 40 years has for the past several years been production manager. During the last few months he has been acting as general factories manager for the company during his predecessor's illness and following his death.

GERMANS HONOR PARMELEE

Dr. C. W. Parmelee, head of the Department of Ceramic Engineering, University of Illinois, has been notified of his election as an Honorary Member of the German Ceramic Society at its annual meeting held recently in Freiburg, Germany.

LUNDELL HEADS CHEMISTRY DIVISION

Dr. G. E. F. Lundell has been appointed chief of the chemistry division of the National Bureau of Standards, succeeding Percy H. Walker, who recently retired. Dr. Lundell is internationally known for his many contributions to precise analytical methods. Dr. C. E. Waters will succeed him as assistant chief of the division.

- The Society of Glass Technology, Sheffield, England, will celebrate its 21st anniversary on Nov. 9-10.

- Carl L. Bausch, vice-president, Bausch & Lomb Optical Co., has been elected a manager of the American Society of Mechanical Engineers for a three-year term commencing Dec. 10, 1937.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	44.00	48.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.021	.0255-.028
Powdered	In bags, lb.	.0235	.028-.0305
Boric acid (H_3BO_3) granulated	In bags, lb.	.0475	.0525-.055
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07⅛
Cryolite ($Na_3Al F_6$) Natural Greenland (Kryolith)	lb.	.0875	.0925
Synthetic (Artificial)	lb.	.0875	.0925
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	31.50	....
In bags	ton	33.10	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.085	....
In 5 Ton lots	lb.	....	.09
Less than 5 Tons	lb.	....	.095
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	....
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	....
Burnt, ground, in 280 lb. bbls	Per bbl.	2.25	2.25
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	18.00	27.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	Per 100 lb.	....	2.25-2.65
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	....	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Antimony oxide (Sb_2O_3)	lb.	.15	.15½
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03¾
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¼
Rutile (TiO_2) powdered, 95%	lb.	.11-.12	.13-.15
Sodium fluosilicate (Na_2SiF_6)	lb.	.06	.0625
Tin Oxide (SnO_2) in bbls	lb.	....	.60
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .005-.02c higher)		.07	.07½-.08
Commercial, Gran. (Milled .005-.02c higher)		.03	.04-.05

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.50-1.75
(Commercial, 25% Selenium)	lb.	....	.90
Cadmium sulphide (CdS)	lb.	....	1.50-1.60
Chromite	lb.	....	.022
Cerium hydrate			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls	lb.	....	.22-.26
Cobalt oxide (Co_3O_4)			
In bbls	lb.	....	1.67
In 10 lb. tins	lb.	....	1.77
Copper oxide			
Red (Cu_2O)	lb.	....	.20¼
Black (CuO)	lb.	....	.17-.20
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425
Black (Fe_3O_4)	lb.	.04½	....
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$)	lb.	....	.16
Manganese, Black Oxide			
In Paper bags	ton	62.50	64.50-66.50
In Burlap bags	ton	65.50	67.50-69.50
In Casks	ton	70.50	72.50-74.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.40
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	....	.09
Powdered	lb.	....	.09½
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.20⅜
Rare earth hydrate			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	2.00
In lesser quantities	lb.	....	2.10
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06⅝	.07
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	....	.08⅜
Sodium selenite (Na_2SeO_3)	lb.	....	1.80-2.00
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.50-1.55
Yellow	lb.	....	1.50-1.55
Sodium uranyl carbonate	lb.	....	.80-.90
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.25
Yellow orange	lb.	....	1.50

Polishing Materials

		Carlots	Less Carlo
Emery, Turkish	lb.	....	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1	lb.	....	.03¾
Putty Powder	lb.	....	.38-.42
Rotten Stone	lb.	....	.03
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

(*Continued from page* 366)

the behavior of the refractories in service vary considerably and it has been found that some are good for one type of use and some for another. Members of this group have shown up very satisfactorily for many types of glass both with respect to corrosion resistance and freedom from defects of the glass produced. Several patents[9] have already issued on mixes falling in this group.

"Monofrax" H is the term used to refer to mixes of a very high degree of purity in which the constituents of the charge to the furnace are chemically pure materials. One[10] of the most interesting of these is a refractory consisting largely or wholly of beta alumina, one of the less common polymorphic forms of alumina, stabilized by the addition of small amounts of certain oxides to alumina of a very high degree of purity. This mix has excellent casting characteristics and high spalling resistance. In addition this material has shown remarkable resistance to most types of corrosion, particularly the action of alkali compounds in the molten or vapor state. Cast beta alumina refractories are stable at all temperatures up to the melting point and they have shown unusual resistance to corrosion below, at, and above the metal line in glass tanks. They also appear to be remarkably free of any tendency toward the formation of defects in the glass. Necessarily, because of the cost of the raw materials, cast fused refractories belonging to this group are the most expensive.

"Monofrax" K is the designation for another group of mixes which has shown up very well for a variety of uses. The chemical and mineralogical composition of mixes falling in this group vary quite widely, but in general it may be said that they contain 80 per cent alumina or over. In many respects this group seems to have the most universal application. At the same time, it is the cheapest which makes it of particular interest. One patent[11] has already issued on a mix falling in this group.

A number of additional patents on cast fused compositions coming under each of the above groups are on file in the patent office or in process of preparation.

The casting temperatures of the preferred "Monofrax" mixes vary from 3300 to 3800°F. Consequently all of the mixes possess unusual refractoriness. Obviously they have a high load bearing capacity at elevated temperatures. The coefficient of expansion is quite moderate. For example, with a typical mix under a load of 25 pounds per square inch, the maximum expansion up to 1500°C. was 1.43 per cent. Held under the same load at this temperature for 1¾ hours, there was only the slightest shrinkage from the original 1500°C. value—about 0.12 per cent. The mixes vary in weight, depending upon the compositions from about 180 lbs. to 200 lbs. per cubic foot. They also vary in hardness from about 7.5 to 9.0 on the Mohs scale. Obviously, because of their dense structure they have a somewhat higher thermal conductivity than a bonded refractory, this property varying with the mix.

Manufacturing Technic

"Monofrax" is cast in somewhat the same manner as a metal except for those changes which are necessary, in view of the inherent differences in properties of a ceramic substance on the one hand and a metallic material on the other. The manufacturing operations are being conducted at the Niagara Falls plant of The Carborundum Company, where cheap power is available as well as a wide knowledge of electric furnace operation. Four different electric furnaces are being used for the casting of "Monofrax." They vary in size from that capable of holding only about a hundred pounds of mix up to one capable of casting blocks a ton or even more in size. The steel shells of all four furnaces are water cooled, the raw batch itself acting as the shell lining. The "Monofrax" is cast into molds, the mold material depending upon a number of factors such as the mix composition, its pouring temperature, the shape required, etc. Because of the hardness of the material, care must be exercised in securing accurate castings. The hardness of "Monofrax" renders it difficult to cut or grind, though with the technic naturally available at The Carborundum Company plant, this has not been found impossible. "Monofrax" has been cast into an exceptionally large variety of intricate shapes for a variety of purposes, indicating a thorough command of casting technic. A number of patents have already been granted on manufacturing procedure and several more have been applied for.

Future Work

As already indicated, the results from the various tests and installations of "Monofrax" thus far made in commercial tanks have been so encouraging that the active commercialization of the development is now in progress. At the same time, research and technical development is being prosecuted along several different lines. For example, new mixes are being constantly prepared and

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tested with a view to determining their commercial applicability. In view of the very high temperatures inherently necessary in casting and molding "Monofrax," practice is considerably different from that used in the metal foundry. Consequently, considerable study is being devoted to the manufacturing process. A new casting procedure is being investigated which from a number of different standpoints shows unusual promise. A new mold technique is also proving quite satisfactory. It is planned to report further developments from time to time as advance in the developments warrant.

Acknowledgment should be made of the excellent and painstaking work of Dr. R. C. Benner, Director of Research for The Carborundum Co., and his associates, and to Dr. E. W. Tillotson of the Mellon Institute for his wise counsel throughout the progress of the development.

[1] U. S. Patent 492,767, filed May 1892 and granted Feb. 28, 1893.
[2] U. S. Patent 659,926 (Oct. 16, 1900).
[3] U. S. Patent 906,339 (Dec. 8, 1908) to F. J. Tone.
[4] U. S. Patent 1,001,497 (Aug. 22, 1911) to T. B. Allen. U. S. Patent 1,448,010 (March 13, 1923) to F. J. Tone.
[5] U. S. Patent 1,524,030 (Jan. 27, 1925) to M. L. Hartmann.
[6] The System: $Al_2O_3.SiO_2$ by N. L. Bowen & J. W. Greig, J. Am. Cer. Soc., 7, 238 (1924).
[7] U. S. Patent 1,615,750 (Jan. 25, 1927) to Gordon S. Fulcher.
[8] Trans. Electrochemical Society, 68, 22 (1935).
[9] U. S. Patent 2,017,056 (Oct. 15, 1935) to G. J. Easter. U. S. Patent 2,019, 208 (Oct. 29, 1935) to H. N. Baumann, Jr., and Chas. McMullen. U. S. Patent 2,019,209 (Oct. 29, 1935) to R. C. Benner and H. N. Baumann, Jr.
[10] U. S. Patent 2,043,029 (June 2, 1936) to H. H. Blau and H. N. Baumann, Jr.
[11] U. S. Patent 2,063,154 (Dec. 8, 1936) to George J. Easter and Chas. McMullen.

COATING GLASS WITH NOBLE METALS

A new way of coating plates of glass, enamel and quartz with almost atom-thick layers of gold, silver, platinum and other precious metals so that neither mechanical, electrical nor chemical forces will strip them off, is revealed in a patent granted to P. Alexander, of Brussels, Belgium.

The inventor has found that by first applying an almost atom-thick coating of some baser metal, such as iron, nickel, or cobalt to the surface, the layer acts like "glue" to hold fast the top coating of the more precious silver, platinum, or gold. In an example of the method, while the plates to be coated are heated, the "glue" layer of nickel is deposited by what is called "cathodic dispersion." In this method the nickel is electrically broken into atoms and these are permitted to condense on the quartz plate to form a nickel layer of about four ten-millionths of an inch thick. In the same way the layer of platinum is deposited on top of this.

Such coated plates, states the inventor, can be heated to high temperatures without the layers cracking off. They can be used instead of wires for electric resistances. Sulfuric, hydrochloric, and nitric acids, even in concentrated solution, it is claimed, do not dissolve the layers away. Nor will they oxidize or rust—*Science Digest*, Oct. 1937.

POTATOES MAY PINCH HIT FOR GLASS

The *Chemisch Weekblad*, Holland, reports that a four-year program of research to broaden the industrial outlets for potato starch has resulted in the development of a substitute for glass. The new material is reported to have all the transparency of glass and more, because it is transparent to the short wave lengths of light which carry the health-giving properties of sunlight. The new product, which is called "Anras glass," can be colored if desired.